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Creating A Stormwater Runoff Model For The City Of Oxford, Mississippi: When It Rains, Where Does That Water Go?

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CREATING A STORMWATER RUNOFF MODEL FOR THE CITY OF OXFORD, MISSISSIPPI: WHEN IT RAINS, WHERE DOES THAT WATER GO?

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By

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ABSTRACT

The City of Oxford, Mississippi (home of the University of Mississippi) has experienced, in recent years, a rapid growth of urbanization. This rapid increase creates more impervious cover, such as bridges, roads, parking lots, etc., which can cause a stress on the capacity of stream load and causes flooding. To correct this, storm water management is needed in the city. This stormwater runoff model uses data collected from rain gauges, soil data from SSURGO and published soil infiltration rates from a Lafayette County Soil Survey, impervious cover created from LiDAR and aerial photography, published evapotranspiration rates, and storm drain locations provided by the City of Oxford Planning Department. This model uses high resolution LiDAR for a detailed topographic model. Impervious cover was modeled using methods using either 1) a conditional statement using zero, 2) a conditional statement using an optimized threshold value or 3) hand editing. The flow direction and a weighted raster, one that incorporates the values of rainfall, evapotranspiration, impervious cover, and soil infiltration rate, is used within the flow accumulation model to achieve a stormwater runoff model. Nine pour points were determined capture storm water outfalls from the city. It is found that there is a significant influx of water that flows into the city. The eight pout point (on Burney Branch Creek, to the south side of the city) has the maximum outflow was found to be from Burney Branch on the south side of the city. The second largest outflow was from Davidson Creek on north side of the city.

DEDICATION

This thesis is dedicated to my grandpa, Harold Francis Weatherwax, who pushed me more than most to finish this thing. I love you, Grandpa.

LIST OF ABBREVIATIONS AND SYMBOLS

AOI	Area of Interest
BMPs	Best Management Practices
cm	centimeters
CREA	Complementary Relationship Areal Evapotranspiration
EPA	US Environmental Protection Agency
ET	Evapotranspiration
DEM	Digital Elevation Model
DSM	Digital Surface Model
DTM	Digital Terrain Model
GPS	Global Positioning System
In/hr	inches per hour
ISB	Ipswish River Basin
km	kilometer
m	meters

MARIS	Mississippi Automated Resources Information System
MIUHET	Minnesota Urban Heat Export Tool
PRISM	Parameter-elevation Relationships on Independent Slopes Model
SSURGO	Soil Survey Geographics Database
SWM	Storm Water Management
SWMM	Storm Water Management Model
TB	Terabyte
TSS	Total Suspend Solids
USDA	United States Department of Agriculture
USGS	United States Geological Survery

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INTRODUCTION

The city of Oxford, Mississippi (home of the University of Mississippi), is experiencing rapid urbanization and like many small municipalities, lacks important baseline information critical to planned development. The city grew 18% between 2010 and 2016 and is considered to be the fastest growing city in Mississippi (Harris, 2016). One aspect of development is that the city of Oxford must take into consideration patterns storm water retention and drainage. Increased urban development leads to increase of impervious surfaces from streets, parking areas, and buildings, and can stress capacity of local streams and results in hazardous flooding. The objective of this project is to create a baseline storm water budget for the city.

Oxford is situated within the region of highest elevation in Lafayette County, resulting in minimal surface water inflows into the city. Surface water input is almost entirely from rainfall, (although a measurable amount falling just outside the city limits drains into the city), with only minor input from residential and commercial watering systems. The city lies on a surface water divide with all surface drainage flowing to either the Sardis Lake Basin to the north or the Enid Lake Basin to the south. The storm water budget model being created will comprise rainfall, estimates of irrigation volumes, soil infiltration and natural surface runoff, impervious surface runoff, redistribution of storm water runoff through drains and piping, and estimates of evaporation loss. All data were incorporated into ArcGIS® file geodatabases for model development. The final product is a dynamic model, based in GIS and readily modifiable, that will permit calculation of surface water runoff and flooding potential, and be useful as a planning tool in evaluating changes associated with continued urban growth and development in Oxford. This model can help the city understand the present storm water flow patterns and predict future flow patterns of storm water with new developments of impervious cover.

PREVIOUS WORK

There are dozens of different models for stormwater management (SWM) or for urban stormwater runoff because each watershed is different. These differences comprise physical characteristics of the watershed, such as its shape, slope, soil stability, and etc., and will react differently to different weather events, such as intensity of the rainfall, snowfall, temperature, and climate change (Hixon, 2015). There is not a SWM system in place in the city of Oxford, however, there are a number of models for SWM in other cities.

In one case, Borris et al. (2014) use the Storm Water Management Model (SWMM) to see how pollutants, total suspended solids (TSS) in particular, are moved through the current stormwater runoff in rainfalls of different climate projections for northern Sweden. The SWMM was created by the US Environmental Protective Agency (EPA) in 1970 and chosen by Borris et al. (2014) for the successful application and continuous updates of the model. This model can simulate stormwater quality and those quality processes, such as runoff, outflows and water traveling through sewage systems. These authors used the default settings of the program using only surface runoff. They also used a kinematic wave approach in the SWMM to find the physical characteristics for each of the different, individual catchment areas. The dependent variables of this model were land-use, street sweeping, dry weather, and wash-off properties in rainfall events.

Another model that was created and applied comes from the Abejona River watershed in Boston, Massachusetts, United States (Perez-Pedini, 2005). This model was created to find the best places for infiltration-based best management practices (BMPs) for SWM. This helped identify ideal locations for detention ponds for this particular watershed. The model was made with an “event-based hydrologic and optimization model” which uses soil and land-use data that can be manipulated to find locations for the infiltration-based BMPs. It was important to find these locations in order to minimize flood outfalls from the watershed.

Janke et al. (2013) created the Minnesota Urban Heat Export Tool (MIUHET) because the temperature of the water in the watersheds is important to the streams within the area of Plymouth, Minnesota. They found that the water temperature changes are harmful to ecosystems, with an increase temperature associates with increased runoff rates and loss of infiltration. Janke et al., (2013) investigated several other SWM but found many limitations in those models. MIUHET simulates stormwater runoff and the heat that flows in the urban subwatersheds throughout the city for either one specific or multiple rainfall events. MIUHET incorporates several aspects of SWM and has three main components: (1) movement of heat and water through the urban and rural land-uses with a combination of impervious and pervious surfaces that drain into a singular outflow point, (2) the movement of heat and water through manmade structures, such as piping, sewage lines, channels, (3) simulation of water storage and hear transfer through BMPs.

In Blacksburg, Virginia, Hixon et al. (2014) created a very detailed hydrologic model to review seven SWM models in place at this location, in order to evaluate the effectiveness of SWM strategies in Blacksburg. Hixon et al. (2014) also reviewed several other SWMs in 2 other areas: Maryland and Colorado. In Prince George’s County, Maryland, US, a low impact development SWM was made. This model strategy is heavy on infiltration and retention with predeveloped runoff properties and rainfall of 24 hours. The Urban Drainage and Flood Control

Districts that services 40 regions in Colorado was also reviewed by Hixon et al. (2014). This model included pre- and post-urban development of runoff volumes per acre and a range of storm types and severity.

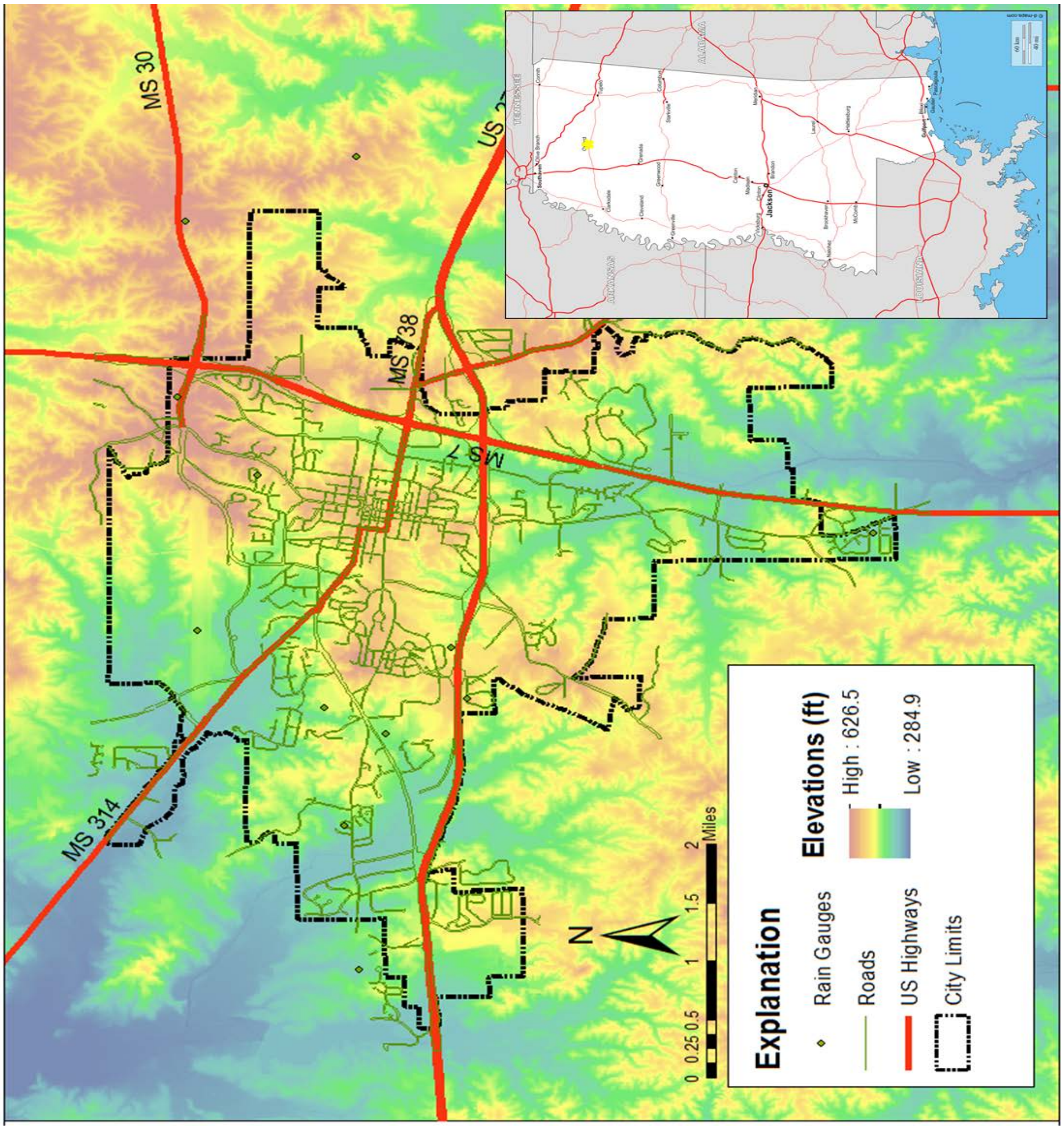

FIGURE 1: Elevation Map of Oxford, Mississippi with rain gauge locations.

The city of Oxford covers 16.5 square miles in center of Lafayette County in northern Mississippi. The highest point of Oxford is in the center of the University of Mississippi (Figure 1).

Oxford drains into the lakes to the south and north of the city: Enid Lake and Sardis Lake respectively. The climate of Lafayette County is characterized by short, cool winters with an annual average temperature of 30°F and long, humid, hot summers with an average temperature of 90°F (Weathersparks.com, 2015). Oxford has an annual average precipitation of approximately 58 inches annually (Morris, 1982 and U.S. Climate Data, 2017).

Soils

Geologically, Oxford is situated on Eocene age Claiborne and Wilcox Group sands and clays. During the Pleistocene loess covered Lafayette County, along with alluvium deposited by the Yocona and Tallahatchie Rivers and their many tributaries (Morris, 1981). Oxford has very little loess remaining as a result of the erosional processes. There are two major soil types within the city: classified as Smithdale-Lucy-Lexington and Lexington-Loring-Providence. There are minor soils throughout the city and county: classified as Ochlockonee, Smithdale-Udorthents complex, Oaklimeter, Ochlockonee-Brono complex, and Arkabutla (Figure 2).

Smithdale are loamy marine deposits that have a slight erosion hazard. The Smithdale (7F) is a sandy loam that is well drained, that has moderate to moderately steep slopes, a 15 percent to 35 percent. The top surface, the first five inches, of this is soil are dark brown sandy loam. The lower portion of this soil, approximately 80 inches in depth, consists of red sandy loams with lenses of uncoated sand grains. The permeability of this soil is 0.6 to 2.0 in/hr from the surface to five inches and

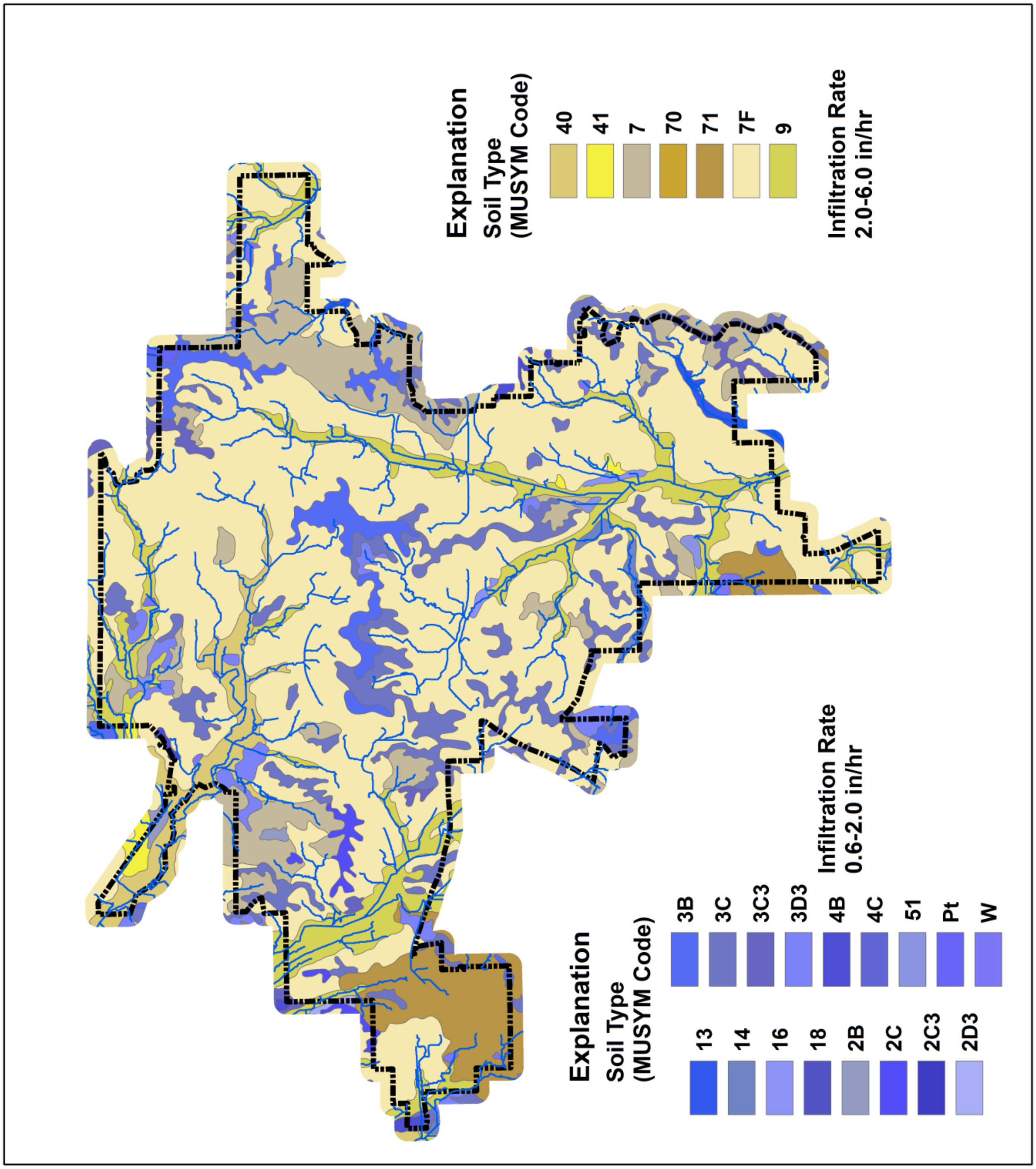

FIGURE 2: Soil map of Oxford, Mississippi

decreases to 0.6 to 2.0 in/hr at the depth of five to 22 inches. At the bottom of this soil profile, a depth of 22 to 80 inches, the permeability rises back to the 2.0 to 6.0 in/hr. The Smithdale-Udorthents complex soils (7) are intermingled and gullied. The Smithdale portion of this complex is very well drained and moderately steep on the upland side with narrow ridges between the gullied that are composed of loamy material. Smithdale soils make up approximately 50 percent of the area of interest. The first five inches are dark yellowish-brown in color and are composed of sandy loam. At a depth of 25 inches, the sandy loam become a reddish-yellow sandy clay loam. Further down to 65 inches in depth, the sandy loams are red with lenses of uncoated sand grains. All of the Smithdale soils are very strongly acidic and moderately permeable with a high runoff rate and the erosion hazard rate is moderate to high. The Udorthents portion is loamy material that is severely eroded in the gullied. This portion of the complex makes up approximately 35 percent of the area and is strongly acidic to extremely acidic where the permeability varies. The runoff is very rapid in this soil and the erosion hazard is very high. From a soil depth of zero to five inches, the permeability of the Smithdale-Udorthents complex is rapid, 2.0 to 6.0 in/hr, then the rate drops to a rate of 0.6 to 2.0 in/hr from five to 22 inches. At the base of the complex, 22 to 80 inches, the rate increase, back up to 0.6 to 2.0 in/hr

Lucy soils are loamy derived from marine deposits, but they are more thickly bedded and have a moderate erosion hazard. The Lucy's permeability rates from the surface to a depth of 28 inches are 6.0 to 20 in/hr, from 28 to 35 inches the permeability decreases to 2.0 to 6.0 in/hr and then decrease to 0.6 to 2.0 in/hr at the remaining depth of 35 to 65 inches. The Lucy is very acidic where upper four inches is dark greyish-brown loamy sand. Below that, up to 28 inches, the Lucy turns to yellowish-brown loamy sand, then at 40 inches in depth the soil changes to yellowish-red sandy loam, and below that, at a depth of 65 inches, the Lucy becomes a mixture red sandy clay loam and yellowish-red sandy loam. The upper portion of this Lucy has a moderately rapid permeability rate and decreases to moderate in the lower portion. The erosion hazard is slight.

Lexington soils are thin deposits of silty loess with a slight erosion hazard. Lexington soils (3B, 3C, 3C3, and 3D3) are well drained with a depth of 6 to 72 inches. The upper portion of the soil is dark brown in color, however most of the original top layer has been eroded away. The first 34 inches, permeability of the top most soil is moderate at 0.6 to 2.0 inches per hour (in/hr). Beyond that to maximum depth of the Lexington the permeability increases to 2.0 to 6.0 in/hr, which is considered moderately rapid. All three of these soils drain well.

Loring soils (4B) are thick deposits of loess and contain fragipans and are considered to be a slight erosion hazard. This soil is moderately well drained and is formed by silty material on ridgetops. The first nine inches of the Loring are yellowish-brown silt loam. From nine to 24 inches the soils becomes brown with a mixture of silty clay loam and slit loam. The lower 41 inches of the soil profile are strong brown in color that is blotched with brown and grey silty loam fragipans that are firm, brittle and compacted. In most places in the area of interest, the original soil layer has been eroded away and is a mix of topsoil and subsoil. The permeability is moderate at 0.6 to 2.0 in/hr for the top 24 inches and the bottom part is 2.0 to 6.0 in/hr in the fragipan. While the Loring is good for row crops in cropland and pastures, this soil is only moderately good for grasses. This soil has limited urban uses, such as for roads, because of the low strength. It is possible to use this soil for urban purposes by using proper designs and installation techniques. The low permeability in the fragipans makes the Loring unsuitable for sewage tanks unless the absorption rate is increased in the septic field.

Providence soils (2C) are thin deposits of loess over loamy soils and also contain fragipans and are considered to be of slight erosion hazards. These last three soils drain moderately to well and also contain silty soils (Morris, 1981). The permeability of this soil is similar to Lexington with rates above: 0.6 to 2.0 in/hr from the soil depth of 0 to 23 inches and 2.0 to 6.0 in/hr from the depth of 23 to 65 inches.

There are several minor soil types within the city. The Kirkville (13) contains on average well drained fine sand, loamy alluvium from broad floodplains. This soil is splotchy gray from the surface to the 24 inches. The Cascilla (13) consists of silty loam from broad alluvial floodplains and is well drained. The Ochlockonee-Brono complex and associates (40, 41) has different permeability rates at different depths. This soil complex is a well-drained Ochlockonee type that consists of loamy alluvium. Ochlockonee soils from the surface down to approximately six inches are composed of yellowish brown sandy loams. The remaining portion of the soil to a depth of 60 inches is compse of stratified layers of dark yellowish-brown fine sandy loam, sand loam, and silt loam. The Bruno part of this complex is excessively well drained and made of sandy alluvium. The surface of this soil, to five inches in depth, is brown loamy sand. From five inches to 60 inches it is composed of stratified layers of dark yellowish-brown sandy loams and loamy sand. For the Ochlockonee from the surface to a depth of 24 inches, the permeability is 2.0 to 6.0 in/hr and from 24 to 60 inches, the rate is the same. The Bruno soils have a much more rapid permeability of 6.0 to 20 in/hr throughout the profile depth from the surface to 60 inches. The Oaklimeter (14) is a silt loam that was created from silty alluvium of flood plains. This soil is occasionally flooded. The first seven inches of this soil are dark yellowish-brown silt loams. Seven to 50 inches, the soils become a light shade of the yellowish-brown of silt loams that also has mottled shades of grey and brown. The lower 15 inches of this soil are mottled brown and grey silt loam. Runoff for the Oaklimeter has a slow rate and is very strongly acidic with a slight erosion rate. This soil is mostly used for cropland or row crops and pastures. It is excellent for grasses and legumes. The Oaklimeter soils have a continuous permeability 0.6 to 2.0 in/hr throughout the depth of the soils from the surface to 65 inches. The Arkabutla soil (51) is a silt loam that was created from silty alluvium of flood plains and is a poorly drained and suffers occasional flooding. The first five inches of this soil are dark brown silt loam. Five to 15 inches, the soil is yellowish-brown silt loam that is spotted brown and grey. From 15 to 22 inches the soil becomes a light brownish-grey silt loam that is blotchy of browns. The lower 38 inches of the Arkabutla is a silty clay loam of mostly greyish-brown that is spotted with shades of brown and grey in it. Runoff is slow in this soil, which has a moderate permeability of 0.6 to 2.0 in/hr throughout the soil profile. Like the Oaklimeter, the Arkabulta is good for cropland comprising row crops and pastures, and has no urban uses because of the flooding potential.

DATA SOURCES

Topography - The topographic model was derived from recent LiDAR coverage of Lafayette County. These data were collected by the United States Army Corps of Engineers (Vicksburg District), Mississippi Delta LiDAR Collection and Processing, Phase II project. LiDAR acquisition for the project was performed between December 17, 2009 and March 5, 2010, with reflights between June 27, 2010 and July 9, 2010. The LiDAR data sets are available from the Mississippi Automated Resources Information System (MARIS) at http://www.maris.state.ms.us/HTM/Data.html. The LiDAR data are available as both point clouds and processed ArcGIS® floating point grids as bare earth or Digital Terrain Models (DTM), synonymous in this case with a Digital Elevation Model (DEM), and Digital Surface Models (DSM), which captures natural and built structures. The gridded data used in this study are supplied using a grid cell spatial resolution of 5x5 feet.

Rainfall - Historic rainfall was modeled stochastically using precipitation data from the PRISM Climate Group from Oregon State University, available online from http://prism.oregonstate.edu. PRISM supplies continuously gridded rainfall on daily, monthly and yearly temporal resolutions (depending on years of coverage) with grid cell spatial resolutions of 4 kilometer (km) and 800 meters (m). Only the coarser resolution is supplied without charge. These historical data were compared, for calibration purposes, to the rainfall data that were collected during this study over a 13-month period in the Oxford area.

Sixteen rain gauges where placed throughout the city in locations unobstructed by treetops and buildings. Locations were chosen to give a roughly equal distribution of gauges across the city, but were restricted to where land owner permission could be obtained. The gauges were monitored over 13 month period, from February 2015 through March 2016. The rain gauges used were glass tubes, 5 inches in height and 1 inch in diameter. The gauges were secured with metal clamps to metal or PVC rods 4 feet in height. Rain measurements were collected and recorded the day after a rain event between 5:00AM and 7:00AM. Rainfall records included the time of the collection and the amount of rain or snow in inches and were recorded in a log book and transferred to an Excel® spreadsheet

Infiltration - Infiltration rates were based on values reported by Lafayette County soil survey (Morris, 1981). These values were recorded as permeability in inches per hour. In this paper these values were used as infiltration as these have the same units and are realistic values of infiltrations for these types of soils. The values of both the low and high range of infiltration were added to the attributes of the soils map in ArcGIS® as inches per hour.

Evapotranspiration – Estimates of evapotranspiration (ET) from watersheds throughout the whole of the United States between 1971 and 2000 were obtained from Sanford and Selnick (2013). These estimates combined three different methods of collecting ET indirectly to create a regression equation used to measure long-term ET for the United States. The methods include a water-balance approach, estimates the potential ET compared with direct measurements of ET, and calculations of the energy balance for land-use or the eddy covariance that is made using an arbitrary distance from the ground. The model additionally used factors of land-use and climate for their model. The range of annual ET for Mississippi was determined to be 71 to 80 centimeter (cm) of rain per year (Sanford and Selnick, 2013). The current study assumes that the ET has not changed that significantly since 2000 and the average 75cm was used. The annual was converted to a daily ET rate in inches (in) using the following equation:

$$\frac{75\ cm * 1in}{2.54\ cm} = \frac{29.53\ in}{365\ days} = 0.081\,\frac{in}{day}\text{ of ET}$$

Storm Sewer Infrastructure – Storm drain and sewage system data were obtained from the City of Oxford, Planning Department, the University of Mississippi, and by direct measurements with a mobile GPS application when locations were unavailable or non-existent.

DATA ORGANIZATION AND PROCESSING

ArcGIS®

The software package ArcGIS®, a product of ESRI® (www.esri.com), was used to process raw data and develop the final runoff model. The GIS datasets were organized into file geodatabases, which allowed for storage and management of up to 1 terabyte (TB) of data. Two geodatabases were used in order distinguish between vector data (using points, lines, polygons to represent discrete features) and raster data (using continuous grids or array to represent continuous variables). The hierarchical organization of geodatasets within the geodatabases was structured in a logical fashion to aid in the management of the disparate types and sources of data sued in this study. Geodatasets within a geodatabase force a common geographic projection on contained features or raster grids, and this is advantageous for efficient organization and processing of these data. The geodatabases defined for this study use two slightly different coordinate systems: NAD 1983 StatePlane Mississippi East FIPS 2301 and the NAD 1983 UTM Zone 16N (with units in meters), although both systems are based on a Mercator projection and a common datum. The reason for this is the reprojection of raster grid data generally requires pixel resampling, and the use of these two related projections minimizes the need to reproject grids. An area of interest (AOI) was chosen such that the extent would include the city limits and along with the rainfall gauges located outside the city limits, along with a rectangular buffer of sufficient extent to ensure that all surface drainage into and out of the city was incorporated. The AOI ranged from about 0.4 miles from the city limits line on the north and west and to 1.0 to 1.4 miles on the south and east, respectively. All data were clipped to the AOI.

Layer Processing

The continuous runoff model is based on the final accumulation grid. The primary geospatial data layer required for calculating base flow accumulation is a flow direction grid. The base flow accumulation calculation assumes a constant value of unity for each input grid cell, and when weighted by a rainfall grid, an ET grid and an infiltration grid results in the final flow model. The runoff model can be farther modified by adding sinks associated with storm sewer infrastructure.

Flow Accumulation I – The starting data for a flow accumulation grid is a corrected DEM representing the topography of the AOI. The DEM was derived from the LiDAR DTM (bare earth) grid. The DTM represents the bare earth elevation after removal of man-made infrastructure such as building and bridges. However, the DTM is not corrected for culverts and other piping that permits drainage under the city highways and streets, which is significant within the AOI. Such structures were located by direct observations, and the DEM grid corrected manually by connecting elevations on either side of such structures.

Using the corrected DEM, a standard ArcGIS process for generating a flow accumulation grid was used. The ModelBuilder flow chart for the process is shown in Figure 4. Essentially, slopes derived from the DEM are used to create a flow direction grid, any closed sinks (generally ponds and sometimes minor errors in the DEM) are filled, and the final flow direction grid is integrated to generate the accumulation number of all grid cells flowing into each downslope cell. The accumulation values are unweighted (i.e., they simply represent the number of upslope cells that feed to any particular downslope cell). Cells with high accumulation are areas where flow is concentrated and can be used to define stream networks. The DEM for the AOI is a grid, each cell representing 25 square feet of area, for a total of 1,753,774,961 square feet or 40,261 acres or nearly 63 square miles (Figure 3).

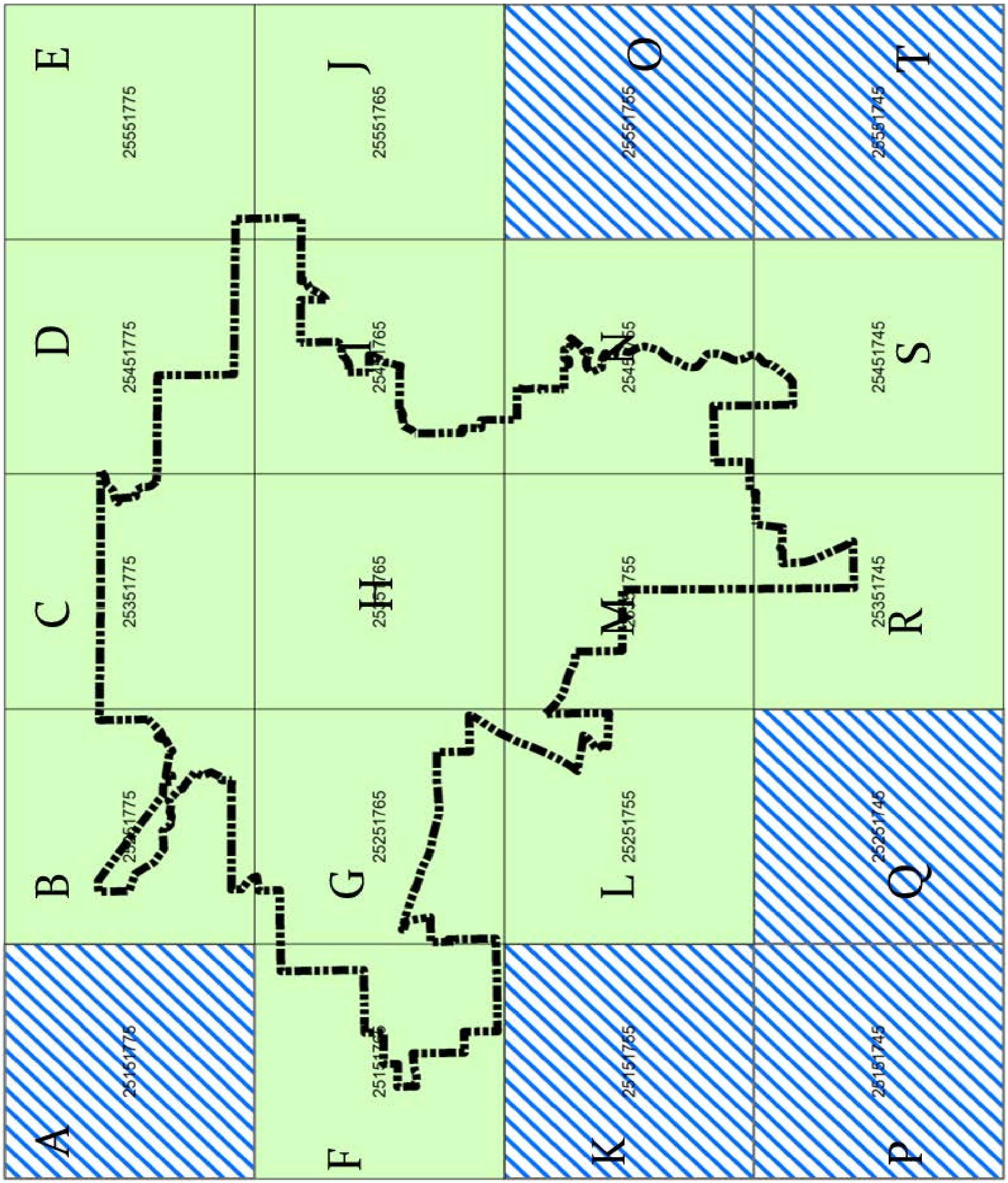

FIGURE 3: Grid of Oxford, Mississippi.

The total unweighted (assuming 100% runoff) accumulation flow for this grid is 146,147,913 cubic feet for a 1 inch rainfall. The area enclosed by the city limits outline of the City of Oxford is 487,277,584 square feet, 10,979 acres or more than 17 square miles. The total unweighted accumulation flow within the city limits is for a 1 inch rainfall is 12,163,895 cubic feet of water.

All processes of how to create the flow accumulation model are shown in a flow chart (Figure 4).

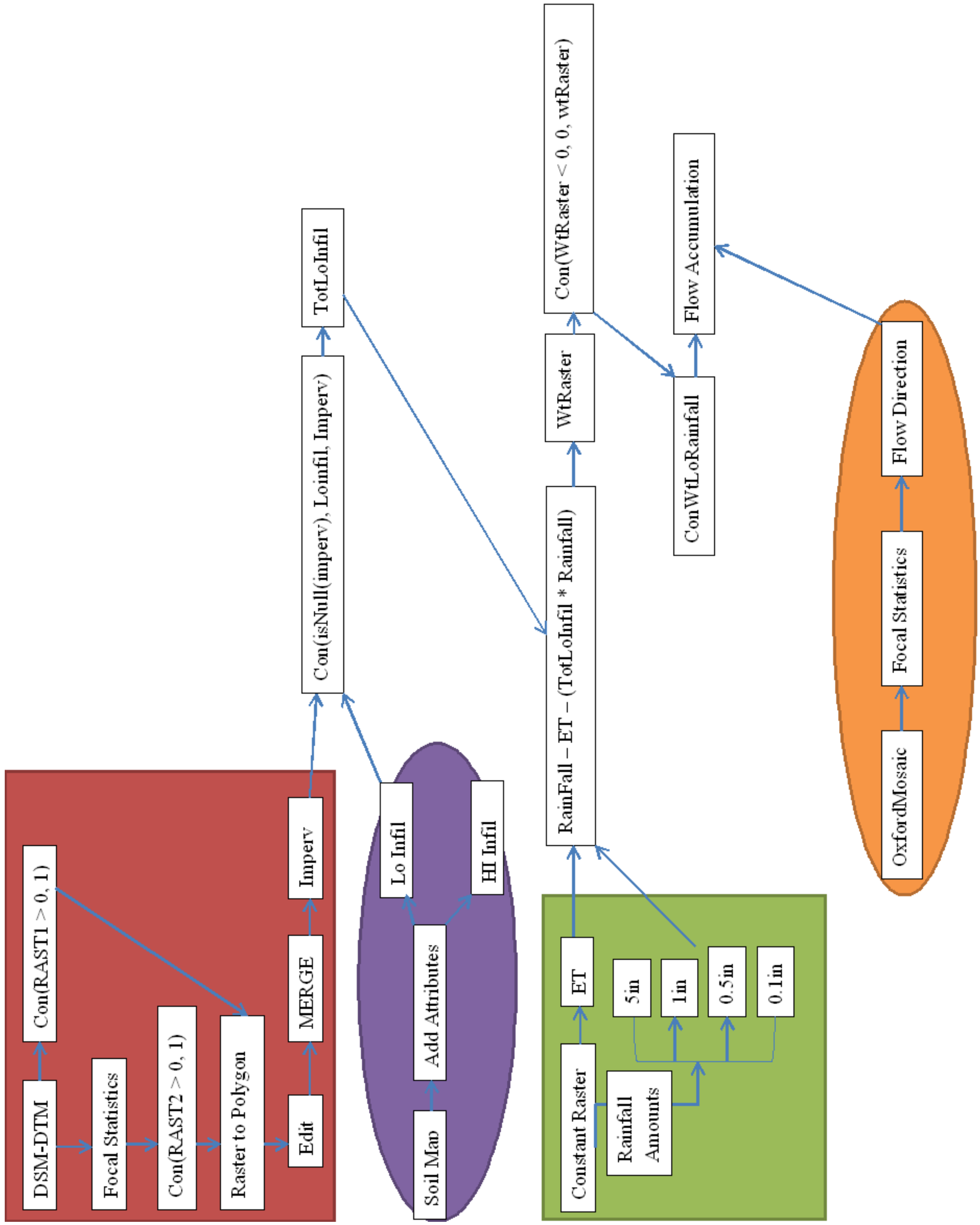

FIGURE 4: ModelBuilder flow chart of the process of creating the flow accumulation maps

Impervious Cover - Impervious cover, characteristic of urbanization is that portion of the AOI for which stormwater cannot infiltrate, resulting in 100% runoff. Areas of impervious cover will change as a result of development within the city, which adds more direct runoff to the nearby streams and negatively impacts the watershed (Alley, 1983). Stream and intercity water bodies are often reconstructed to be able to handle the added loads of water, generally by straightening natural streams, strengthening the banks by the addition of rip-rap, or making them deeper. Alley (1983) showed that there are two types of impervious cover: one is called effective impervious cover, where water is redirected along paths of roads, gutters, and parking lots, that all connect to the nearest stream or body of water within the city; while the other type is called non-effective impervious cover, where water drains into points of infiltration such as off of a roof and into the ground. In this study, the effective impervious areas were found primarily from infrastructure maps of highways, roads, and parking lots supplemented with aerial photography and non-effective impervious areas were found primarily by using LiDAR. Because non-effective impervious cover primarily comprises of building and similar structures (e.g. football stadium), a method was developed to extract buildings footprints from the difference between the DSM and the DTM grids generated form LiDAR grid data.

Because of the data density of the grids, the data were analyzed tile by tile, each tile covering approximately 4 square miles (coverage shown in Figure 3). The initial step was subtraction of the DTM grid from DSM grid, resulting in a raster representing the height of an LiDAR returns above bare earth ground level.

$$HEIGHT = \mathrm{DSM} - \mathrm{DTM}$$

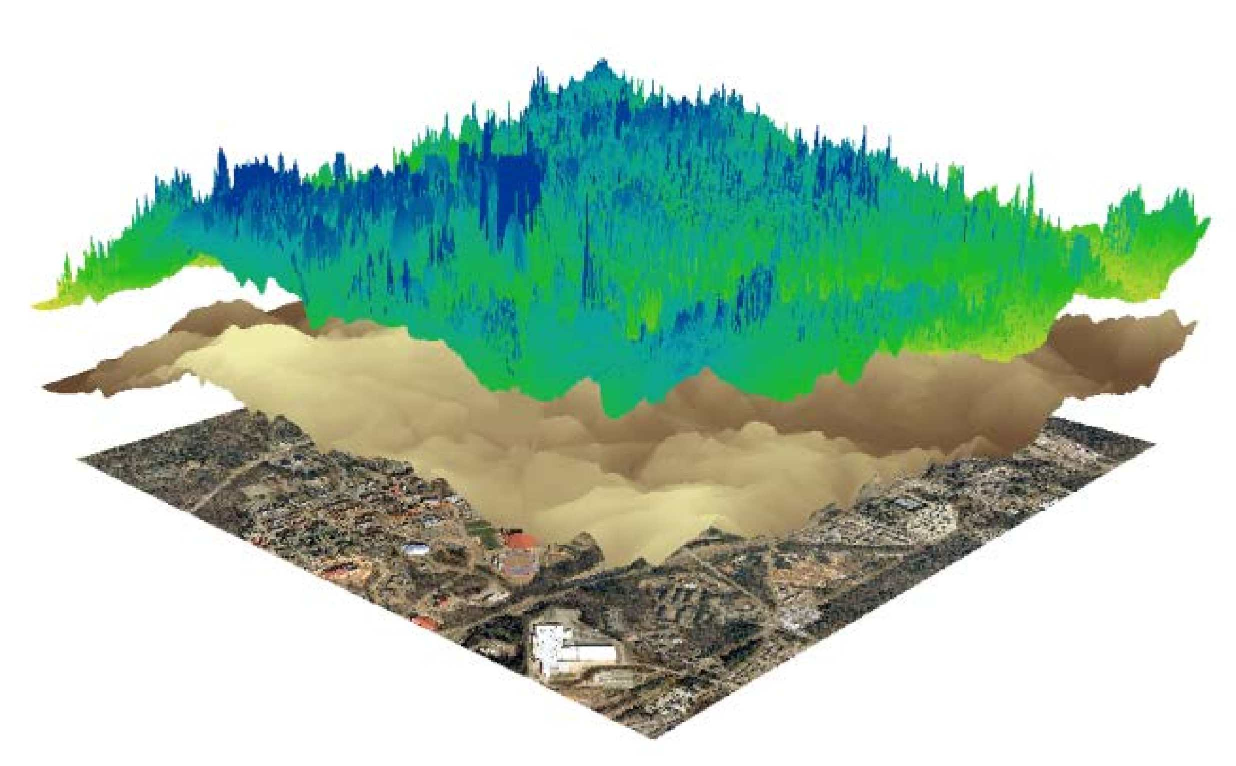

FIGURE 5: The top blue and green layer is the DSM, under that is the DTM (the bare earth elevation), and the last layer is the orthophotograph that was referenced for the building of the impervious cover rasters.

Evaluation of the *HEIGHT* grid could procede in one of three ways:

1) In order to test for isolated large values of HEIGHT, cells were recalculated as the mean value of the neighborhood cells (the target grid cell plus the 8 adjacent cells). The HEIGHT grid was then converted to a binary grid using a conditional statement:

$$BINARY = \text{con}(\text{HEIGHT} > 0, 1)$$

which returns a 1 if the height is 0, and setting the remaining grid cells to NODATA (or null).

The resulting BINARY grid is converted from raster to a vector polygon feature class. Relatively larger, continuous surfaces (primarily rooftops) created relatively orthogonal polygons, whereas trees create small isolated points which can be removed by editting.

2) In some areas, significants tree cover adds excessive noise to the difference grid HEIGHT. In these cases, rather than recalculate the mean neighborhood for the HEIGHT grid, the original HEIGHT grid was processed using a modified conditional statement. The HEIGHT grid was first examined in order to determine a threshold cell value that could distinguish most of the tree cover from the buildings, and this value was used in the conditional statement:

$$BINARY = \mathrm{con}(HEIGHT > \mathrm{threshold}, 1)$$

3) If the automated methods above failed to delinate building coverage effectively, building rooftops were hand digitized from the aerial othorphotography acquired at the same time as the LiDAR data.

When completed, all of the edited polygons tiles were then merged together to create a continuous later of non-effective impervious cover, which was then combined with the roads layer representing highway and street right of ways. This final later was saved as the total impervious cover for the city (IMPERVCOV) (Figure 6).

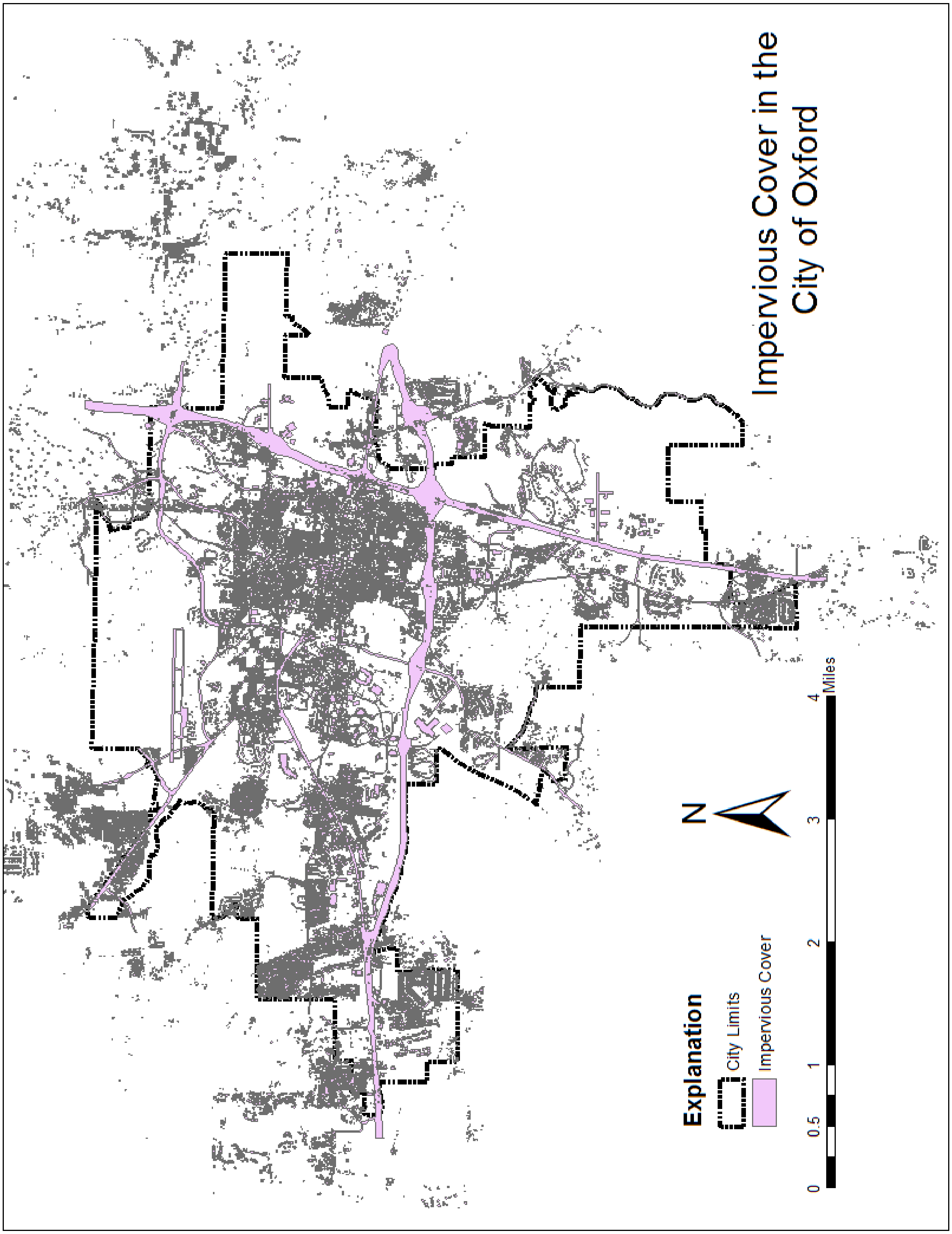

FIGURE 6: Impervious cover within the city

Infiltration – Infiltration estimates were based on surface soil data obtained from the United States Department of Agriculture SSURGO (Soil Survey Geographic) Database (http://www.nrcs.usda.gov/wps/portal/nrcs/details/soils/survey/?cid=nrcs142p2_053627), supplemented with the Soil Survey of Lafayette County (Morris, 1981) for details on soil properties. The soil layer was clipped to the AOI and the soil polygons were attributed with low and high infiltration values in inches per hour (Morris, 1981). The soils of Providence, Loring, Lexington, Kirkville, Cascilla, Arkabulta and Oakimeter classification had a range of 0.6 in/hr to 2.0 in/hr. The soils of Smithdale, Smithdale complex, Smithdale associates, and Ochlockonee-Bruno Complex and Associates classification had higher infiltration rates of 2 in/hr to 6 in/hr. The soil polygon layer was then converted into two raster grids using the values of high and low infiltration rate, respectively. These rasters, labeled as highsoil and lowsoil respectively, were then coverted into infiltration layers using the conditional statement:

$$HIGH = \mathrm{con}(\mathrm{isnull}(IMPERVCOV), \mathrm{highsoil}, IMPERVCOV)$$

and

$$LOW = \mathrm{con}(\mathrm{isnull}(IMPERVCOV), \mathrm{lowsoil}, IMPERVCOV)$$

The results of these conditional statements ensure that the final infiltration grids are continuous with and combine soil infiltration with impervious cover.

Storm Sewer - Storm sewer inlets were known but while storm sewer outfalls were not known they were assumed to lie within the same watershed as the inlets. Storm sewer inlets were therefore implemented as grid cells which absorbed all inflow. This is accomplished in ArcGIS® by modifying the flow direction grid, forcing the grid cell containing the inlet to become a sink by assigning it an invalid flow direction value. All upslope flow accumulation associated with the sink will be absorbed. Storm sewer inlets are therefore treated as grid cells with 100% infiltration.

Rainfall and ET – Rainfall and ET were configured as raster grids of daily rates in inches. The ET is a regional measure, and the estimated value of 0.081 in/day (see previous section for calculation) was applied as a constant grid over the entire AOI. Rainfall can be treated in a similar manner as ET, i.e. as a grid of constant value over the AOI, or rainfall intensity can be modeled as a variable grid. A variable rainfall grid can be generated stochastically or deterministically, in the latter case assigning rainfall rates from the Thiessen polygons derived from rain gauge measurements or alternatively the 4km cells of the PRISM data sets. In each case, the rainfall is given as inches/day.

Weight Grid – The weight grid is a combination of all instantaneous inputs into and outputs from a grid cell, i.e. rainfall minus ET and infiltration/sewer loss. Rainfall and ET measurements are straight-forward, but infiltration rate is proportional to the amount of rainfall. The defining equation is:

$$RAINFALL - ET - (INFILTRATION \text{ X } RAINFALL) = WEIGHT$$

The weight raster represents a range of runoff as both a positive and negative values. ArcGIS cannot calculate a flow accumulation value with a negative weight raster. Negative values also indicate that more water is being pulled from the soil than the soil has. A zero value would indicate infiltration of all the rain in that cell. An additional conditional statement was used to eliminate the negative values and make them all zero.

$$Con(WEIGHT < \; 0, 0, WEIGHT) = ConwtLoRainfall$$

This conditional statement evaluates each cell in the weighted raster for a value less than zero and replaces it with a zero value. Otherwise, the original positive weight raster value is retained.

Flow Direction Grid – The second component of a flow accumulation model is a grid representing the flow direction from upslope to downslope for each grid cell. The corrected DEM (the DEM OxfordMosaic) was used as the elevation grid after all the sinks (sets of grid cells where all flow is inward) were filled. Flow direction was calculated using standard ArcGIS® tools.

Flow Accumulation II – Flow accumulation grids were calculated using standard ArcGIS® tools. The unweighted flow accumulation grid (where the weight for each cell is replaced by unity) was used to generate the maximum runoff case. Under the scale assumptions used in this model, the unweighted flow accumulation represented a 1 inch rainfall over the entire AOI with 100% runoff (i.e., no loss to ET or infiltration). This permitted delineation of drainage areas (watersheds), streams channels, and locations of outfalls.

Pour points were manually placed at locations were outflows crossed the city limits boundary. Some of the pour points were located outside the city limits in order to intercept tributaries that drained areas within the city (Figure 7).

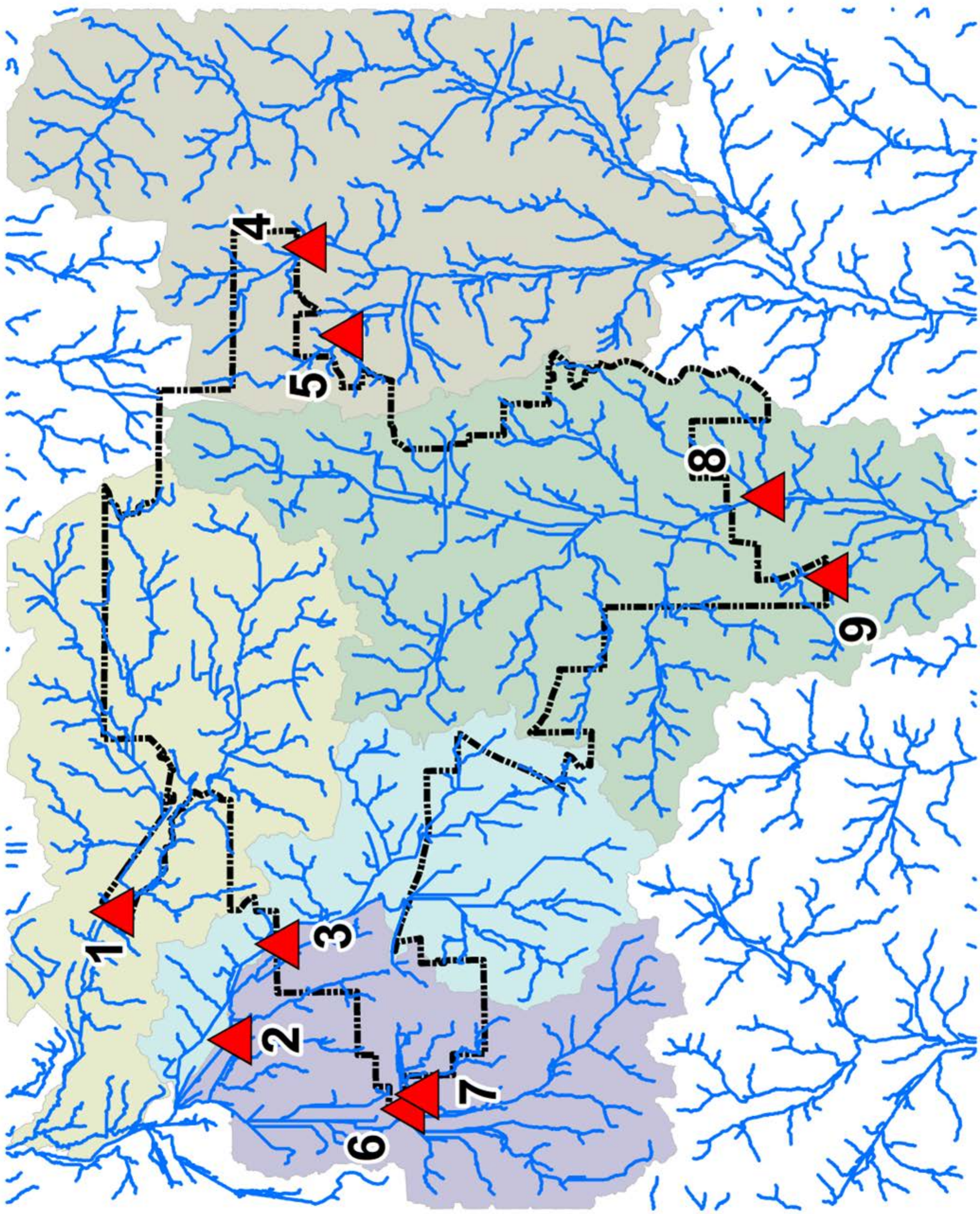

FIGURE 7: Pour point placement with watersheds.

The accumulated grid values at the outfall location represent total daily discharge in through a 25 square foot grid cell and were converted to cubic feet in standard volume units.

The stream channels were created using the accumulation rasters at different threshold to show the detail of the stream network in the city and where the outflow and inflow points are in the city.

PRISM

Parameter-elevation Relationships on Independent Slopes Model or PRISM is an accumulation of monitored climate networks that were integrated using several different modeling techniques and spatial analysis. It was written by a meteorogist to address climate changes (Taylor, abstract). This creates climate datasets that indicate short and long term climate patterns in the United States. All of this was created by the PRISM Climate Group out of Oregon State University. It covers climate patterns from 1985 to the present. The 30-year normal averages were used for this project and were clipped to only include Lafayette County buffered to 50 miles around county to show the different precipitation patterns throughout the area of interest.

RESULTS

Rainfall – Rainfall was based on a constant raster, using different rainfall amounts that were collected over a period of 13 months. The lowest value used was 0.1in, while the highest value was 5in. a rainfall was also used. The variability in the models was also tested with a 1in rainfall. All of the rainfall values were made into constant rasters distributing rainfall city wide. The ET value was represented by a constant 0.081in/day. The infiltration rate of the soil is a constant value, but total infiltration is proportional to the rainfall amount. Rainfall was recorded as total rainfall per day. Infiltration, however, is by the hour and a rain storm does not generally last for 24 hours. Infiltration at the lower rate is multiplied by the total rainfall amount to show the rainfall infiltration into the soil during storm events. TOTLOINFILT raster gave best results as a weight raster because the lower infiltration values represent a more realistic saturation of the soil and represents the rainfall average in the city.

The rainfall data collected showed that the southern part of the city received the most rain over the 13 months of record. Meteorlogically, storms during the winter would enter the city from the southwest and exit to the northeast. As the seasons progressed, this trend would rotate 90 degrees, and the storms would enter the city northwest and exit southeast. Uncommonly, minor storm systems would enter the city from the east.

Nine watersheds were created using the hydrology toolset in ArcGIS®. Four of the watersheds drain into the north into Sardis Lake, while five drain into Lake Enid. There is a clearly defined divide in surface water flow through the city. When the storm sewer inlet drains were found, there were several hundred more inlets on Jackson Avenue than on the other two streets of Lamar Avenue and University Avenue, while Lamar Avenue had the least. The sewer outfalls, though it was not always clear which inlet drain flowed into which outfall, all drain into the tributaries that connect to Toby-Tuby Creek and eventually to Sardis Lake. This creek is intersected by West Jackson Avenue. When there is a heavy down pour, this creek becomes flooded by the all the drainage from the other smaller creeks that lead into Toby-Tuby Creek. Storm sewer drains in cities are the main culprit to the degradation to the intercity streams and outflow water bodies (Burns, 2015). Rainfall was summed over a set Thiessen polygons and the map below clearly shows that during this collection period, the southern portion of the city received the most rainfall, while the north (near the city airport) receives the least amount of rain (Figure 8).

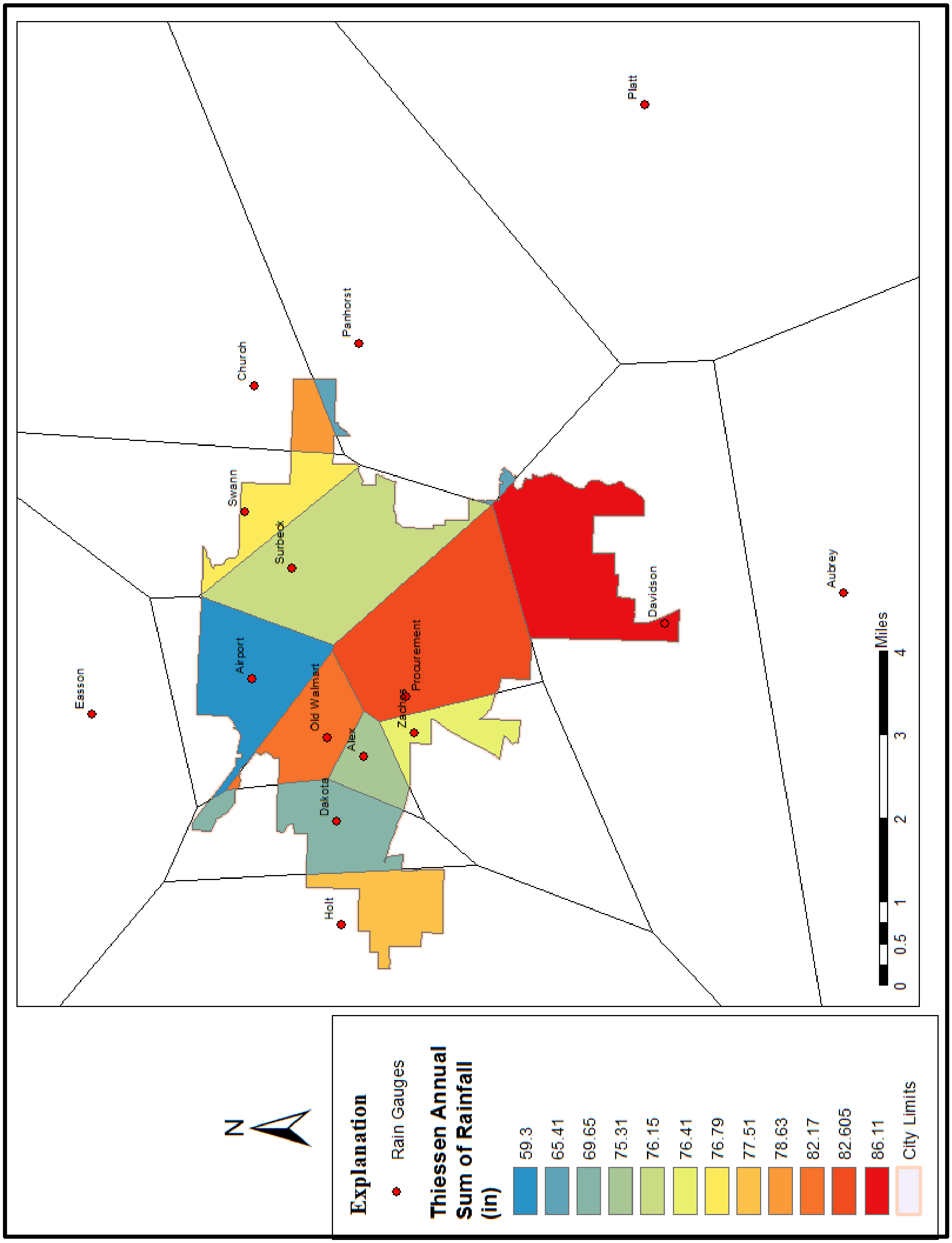

FIGURE 8: Thiessen Polygons of annual rainfall through the 13 month collection.

Impervious Cover – Currently, only six percent of the area of the city is impervious cover. This number will be growing as the city continues to become more urbanized. Impervious cover is not exactly distributed through the city but varies for the different watersheds. The impervious cover for each of the watersheds is shown in Figure 9 and Table 1. Several maps were made to show different accumulation values at the pour points of the city. The city has an area of 478,277,584 square feet. The volume of rain falling within city limit was totaled for each of the modeled rainfalls (Table 2). Runoff - The unweighted accumulation represents the total outflows of a 1 inch rain and has no infiltration (100% runoff). The other accumulation models are weighted by rainfall, ET, and infiltration and are summarized in Table 3.

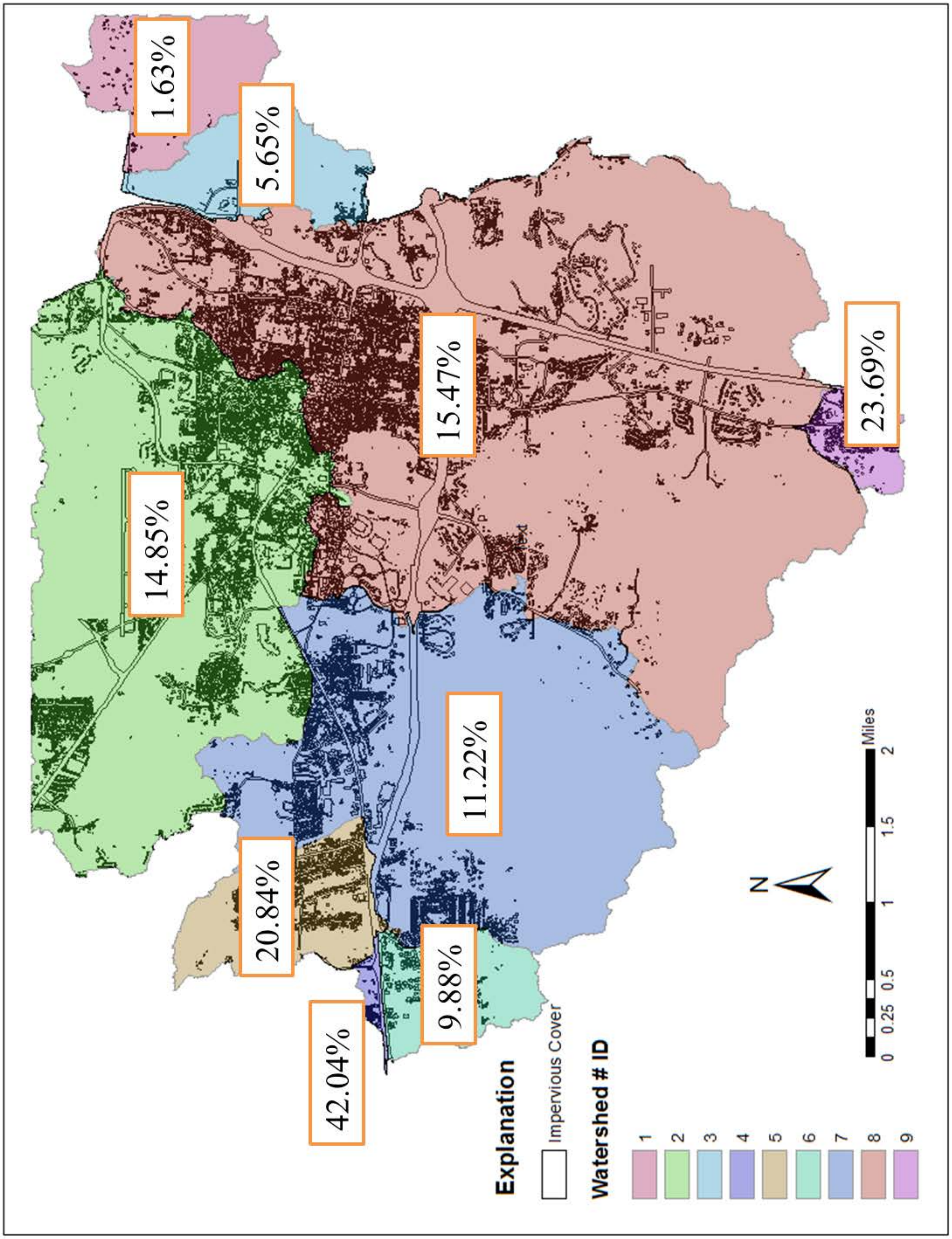

FIGURE 9: Percent impervious cover within the city limits.

Watershed Number	Area of Watershed (ft^2)	Percent Impervious Cover (%)
1	24,484,171	1.63
2	155,991,229	14.85
3	22,260,379	5.65
4	2,097,437	42.04
5	25,481,889	20.84
6	18,250,719	9.88
7	135,393,807	11.22
8	294,443,850	15.47
9	8,509,347	23.69

TABLE 1: Percent impervious cover in each of the 9 watersheds that are in the city.

Flow Accumulation Model

Volume of Water in the City		
Square footage of City	478277584.3	
Rainfall (in)	Rainfall (ft)	Volume of Rain (ft^3)
5	0.42	199282326.8
1	0.08	39856465.36
0.5	0.04	19928232.68
0.1	0.008	3985646.54

TABLE 2: Volume of water entering the city at different rainfall amounts

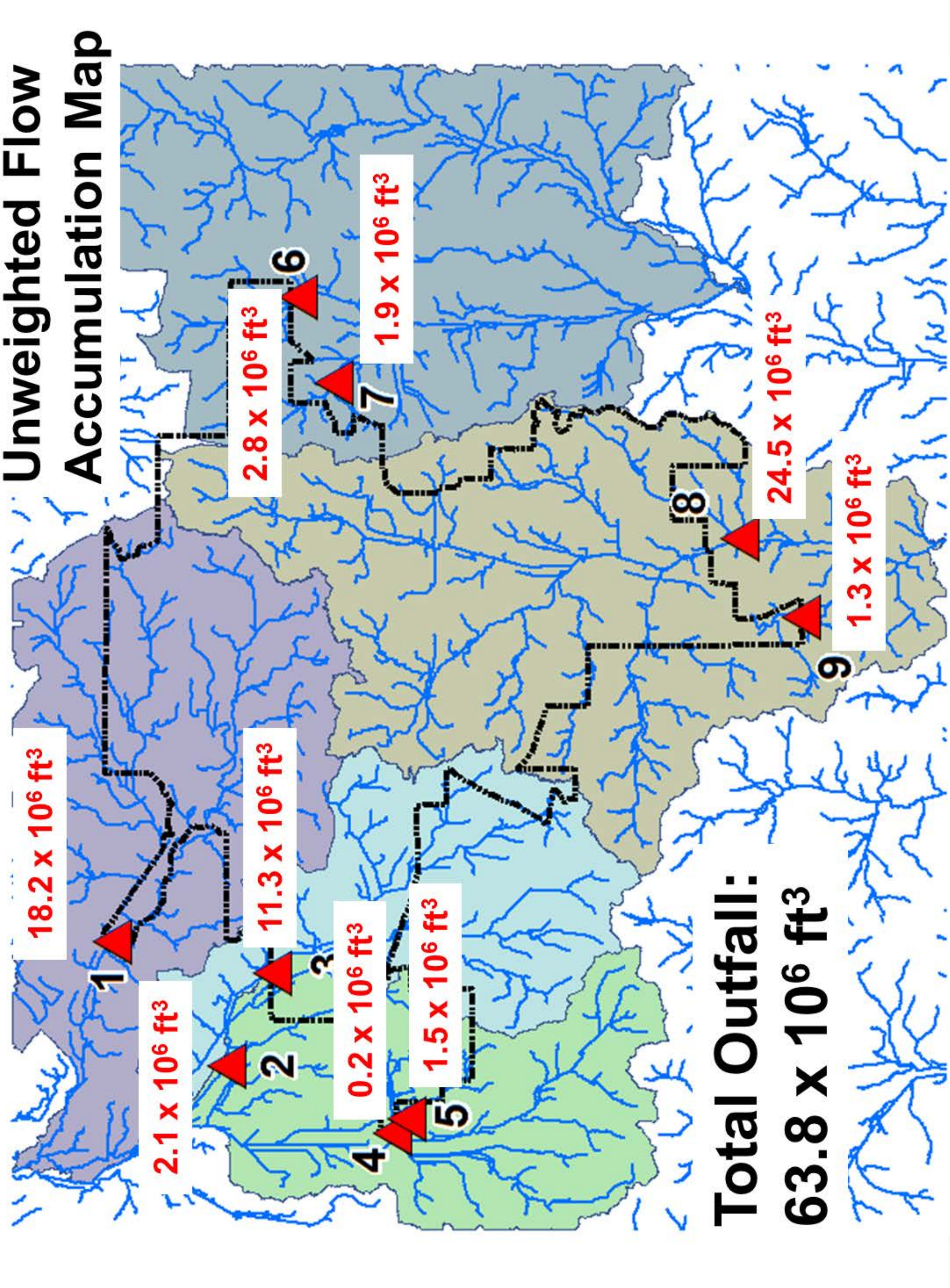

FIGURE 10: Unweighted flow accumulation map of the city.

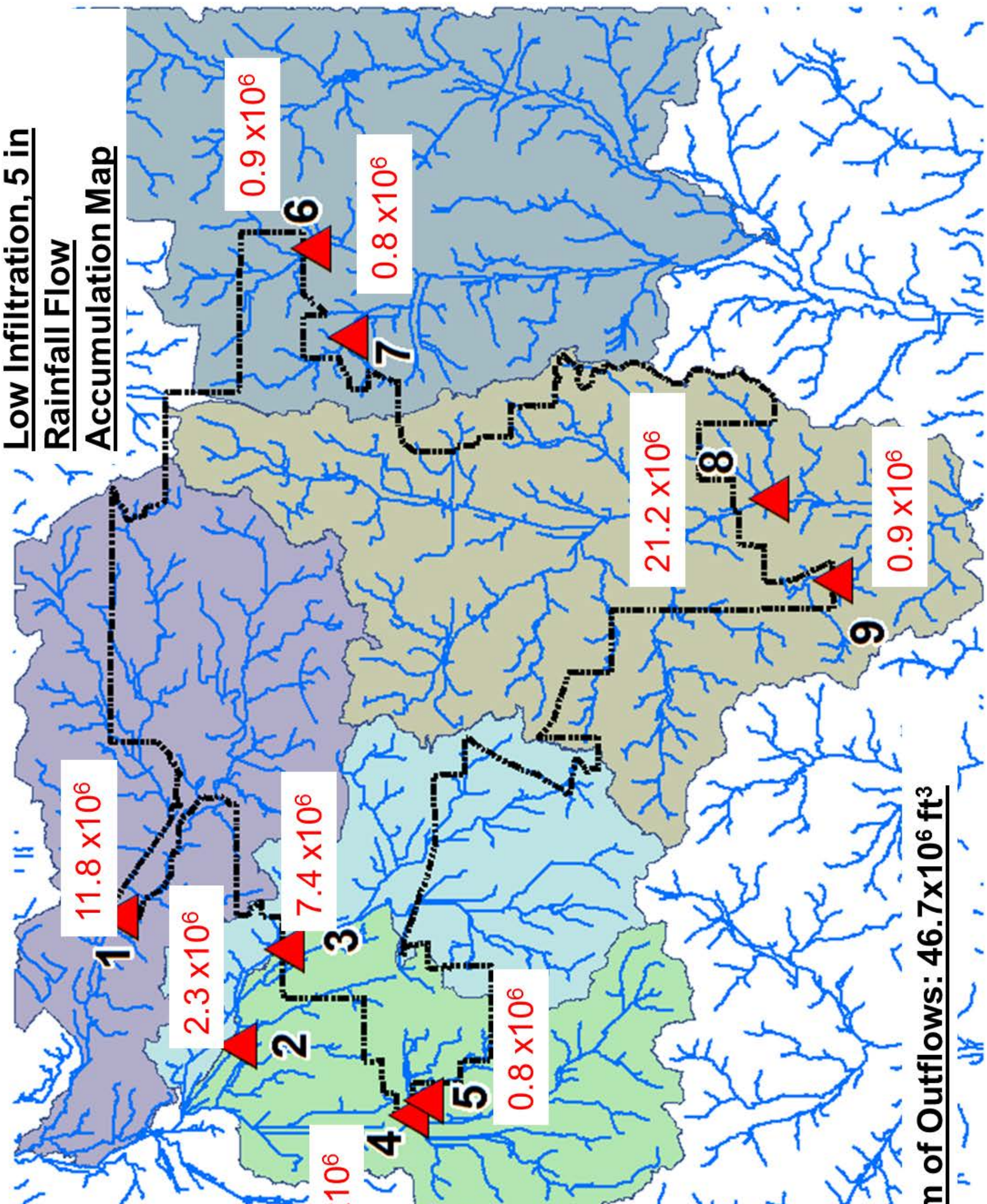

FIGURE 11: Flow accumulation map of the city using low infiltration rate in a 5 inch rainfall.

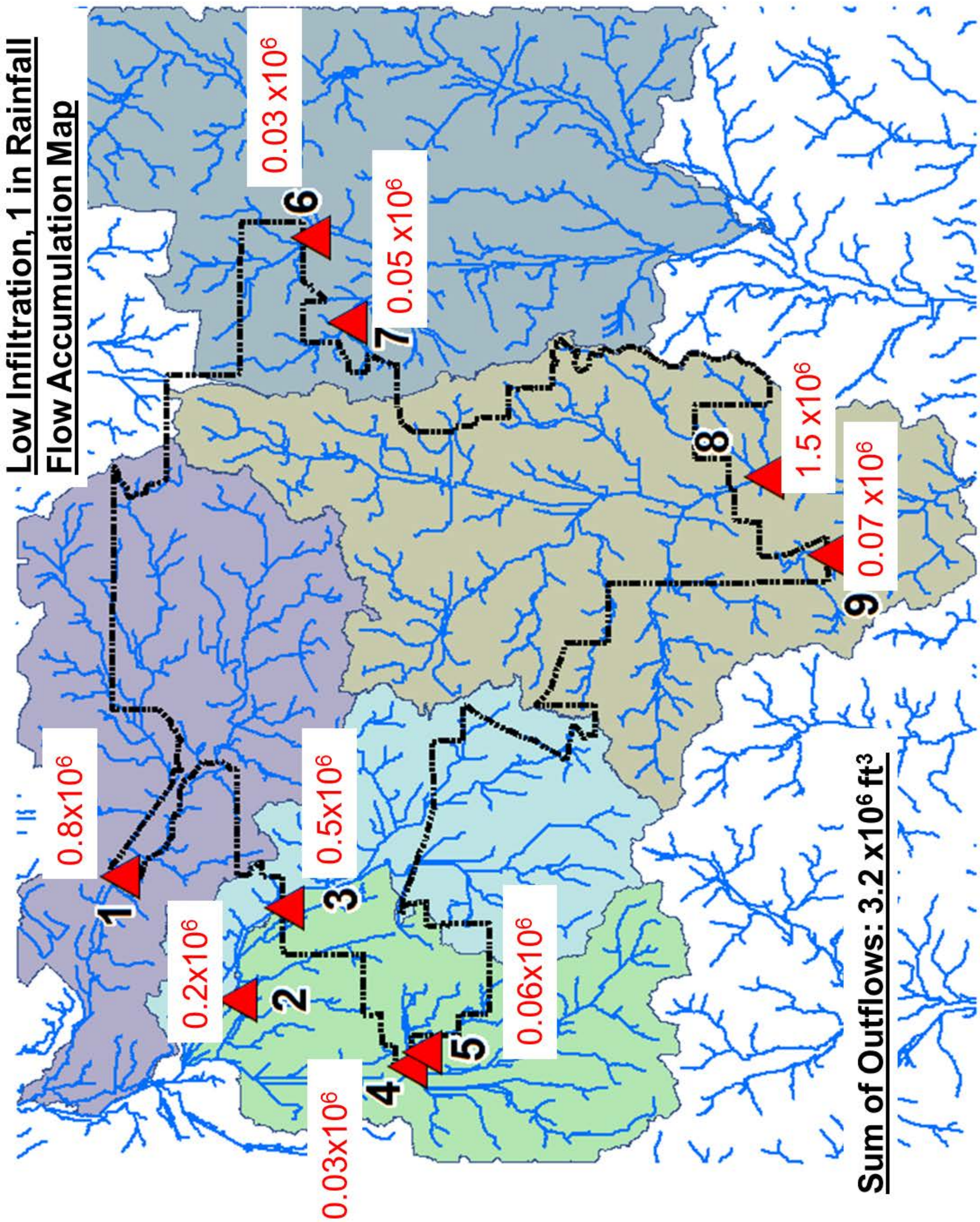

FIGURE 12: Low soil infiltration with a 1 inch rainfall flow accumulation.

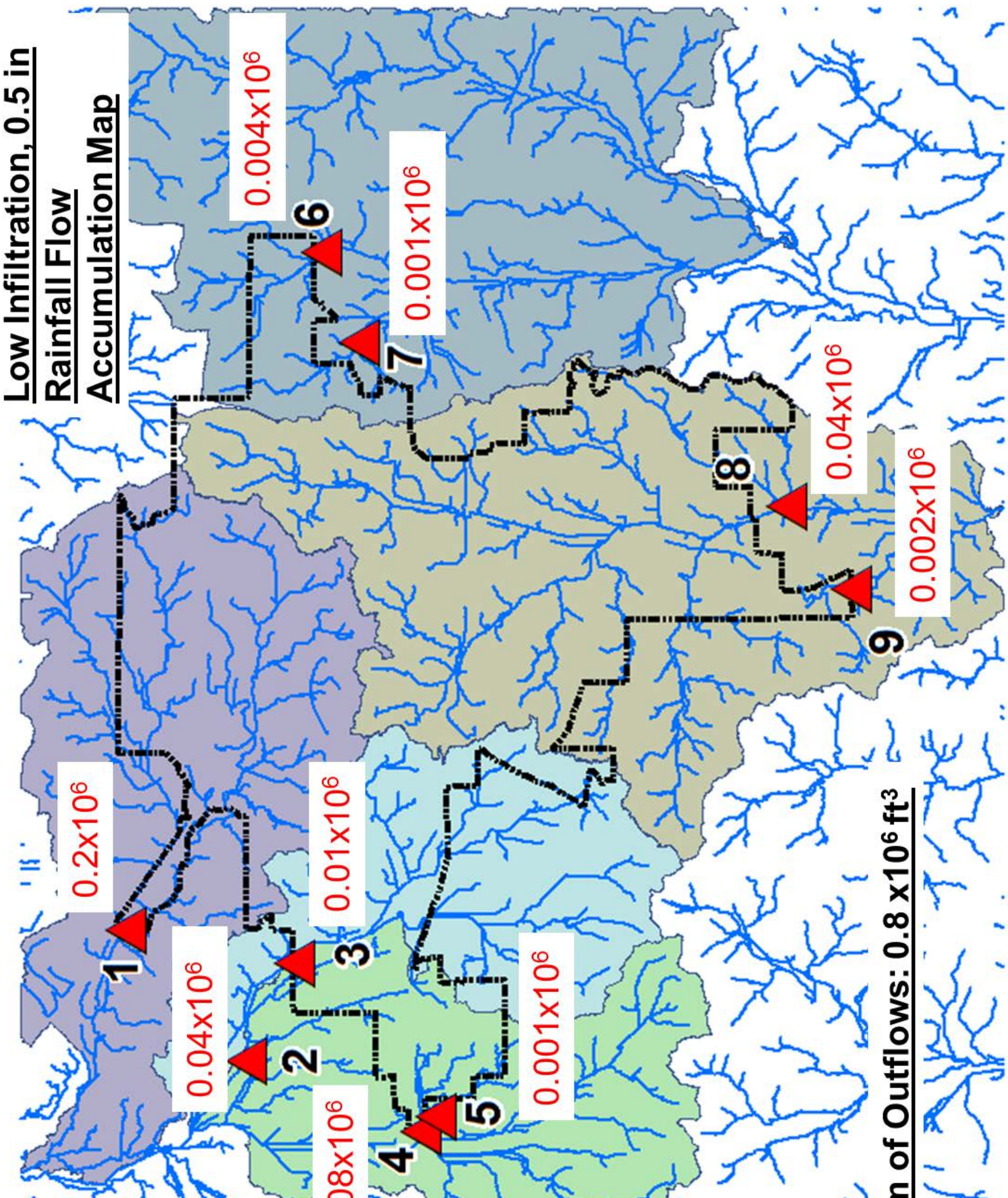

FIGURE 13: Low soil infiltration with a 0.5 inch rainfall flow accumulation.

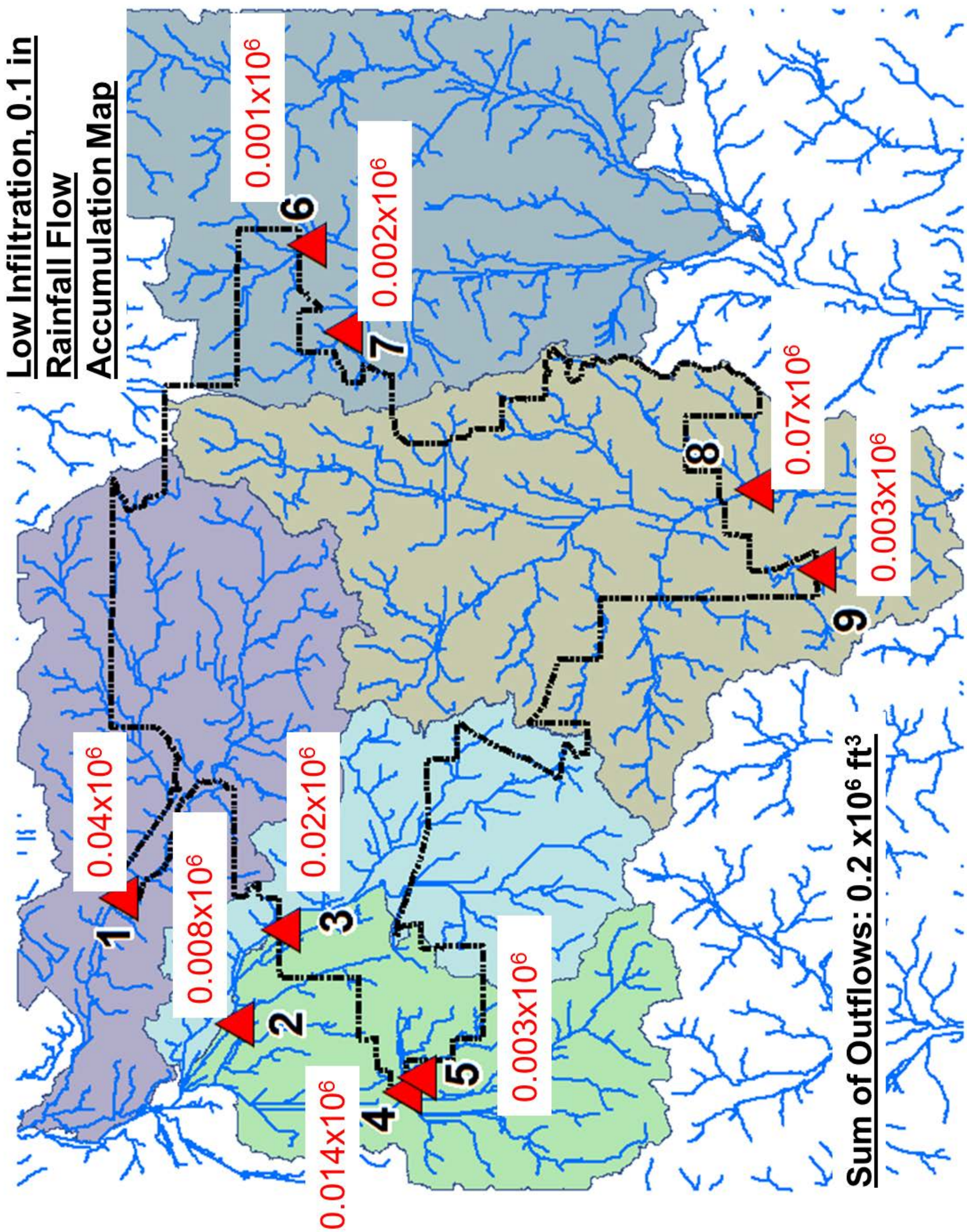

FIGURE 14: Low soil infiltration in a 0.1 inch rainfall flow accumulation.

To Sardis Lake					
Pour Points	1	2	3	4	5
Watersheds	155,991,211	25,481,889	135,393,755	2,097,437	18,250,719
No Weight (ft^3)	18,265,088	2,123,542	11,282,855	174,756	1,520,935
Runoff NoWt (in)	1.41	1.00	1.00	1.00	1.00
Low 5in (ft^3)	11,832,867	2,383,648	7,443,962	321,590	798,106
Runoff (in)	0.91	1.12	0.66	1.84	0.52
Low1in (ft^3)	812,312	172,440	513,906	28,590	56,558
Runoff (in)	0.06	0.08	0.05	0.16	0.04
Low 0.5in (ft^3)	197,373	40,190	125,792	7,852	14,529
Runoff(in)	0.02	0.02	0.01	0.04	0.01
Low 0.1in (ft^3)	39,568	8,435	24,141	1,396	2,874
Runoff (in)	0.00	0.00	0.00	0.01	0.00
To Enid Lake					
Pour Points	6	7	8	9	
Watersheds	24,484,171	22,260,379	294443833	8,509,347	
No Weight (ft^3)	2,763,396	1,855,033	24,536,874	1,268,856	
Runoff NoWt (in)	1.35	1.00	1.00	1.79	
Low 5in (ft^3)	915,873	800,117	21,241,548	922,092	
Runoff (in)	0.45	0.43	0.87	1.30	
Low1in (ft^3)	30,038	49,848	1,468,390	67,432	
Runoff (in)	0.01	0.03	0.06	0.10	
Low 0.5in (ft3)	3,967	11,392	354,035	17,283	
Runoff (in)	0.00	0.01	0.01	0.02	
Low 0.1in (ft3)	1,037	2,003	72,470	3,234	
Runoff (in)	0.00	0.00	0.00	0.03	

TABLE 3: Low soil infiltration rate for various constant rainfalls for each pour point divided by which lake it flows out into.

ROBUST MODELS

Besides constant, city wide rainfall values, this model can be tested with the continuous, variable rainfalls that were recorded through the 13 month collection period. These values can be compared to the standard, constant rainfall values that were made in the model.

The storm sewer street drains can be added to the impervious cover model, to incorporate redistribution of runoff. Though the outfalls of the street drains are unknown, their flow eventually leaves the city at the modeled pour points.

The model can also incorporate actual Doppler radar of storms and the real-time intensity of rain through the city.

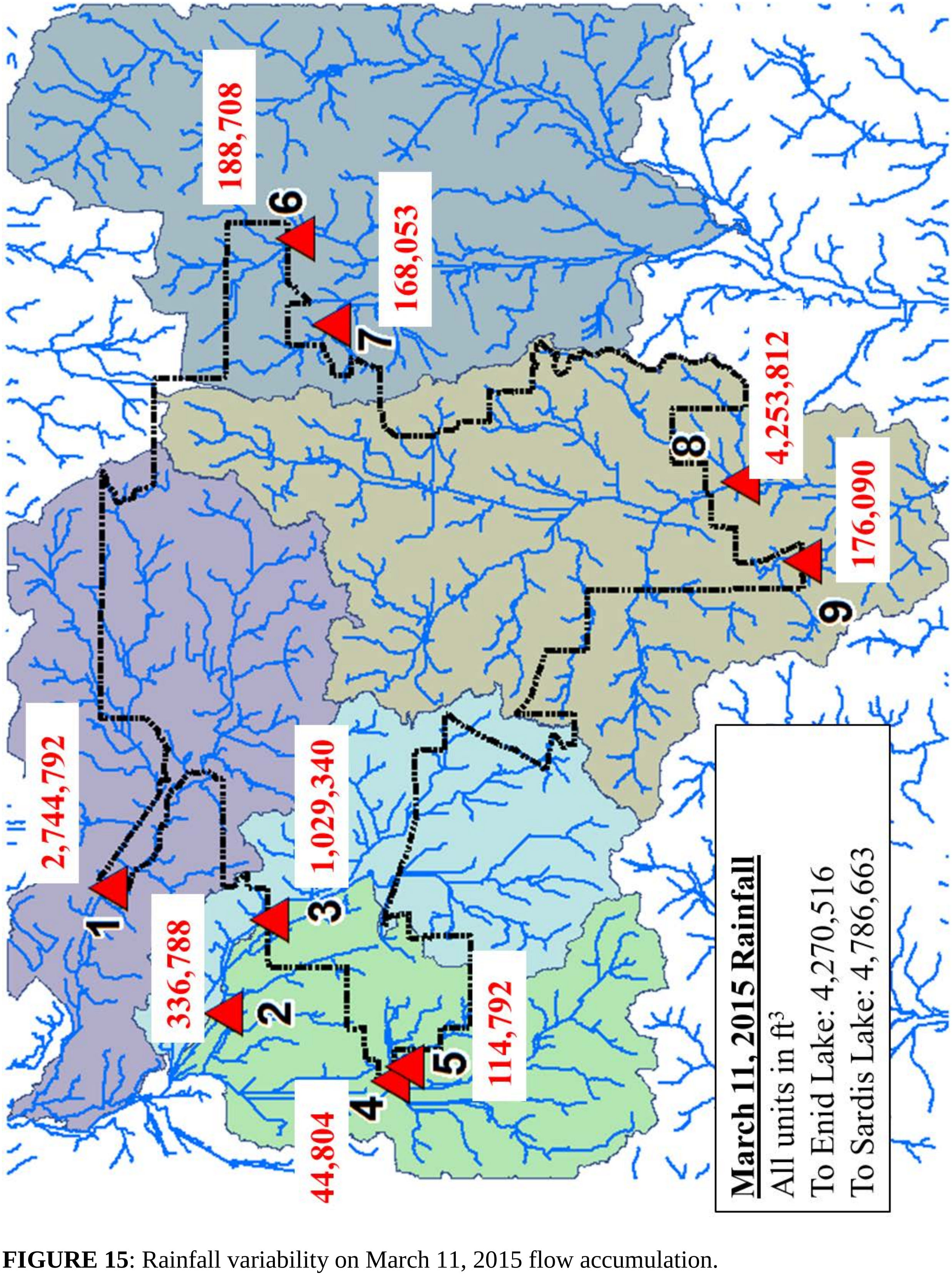

FIGURE 15: Rainfall variability on March 11, 2015 flow accumulation.

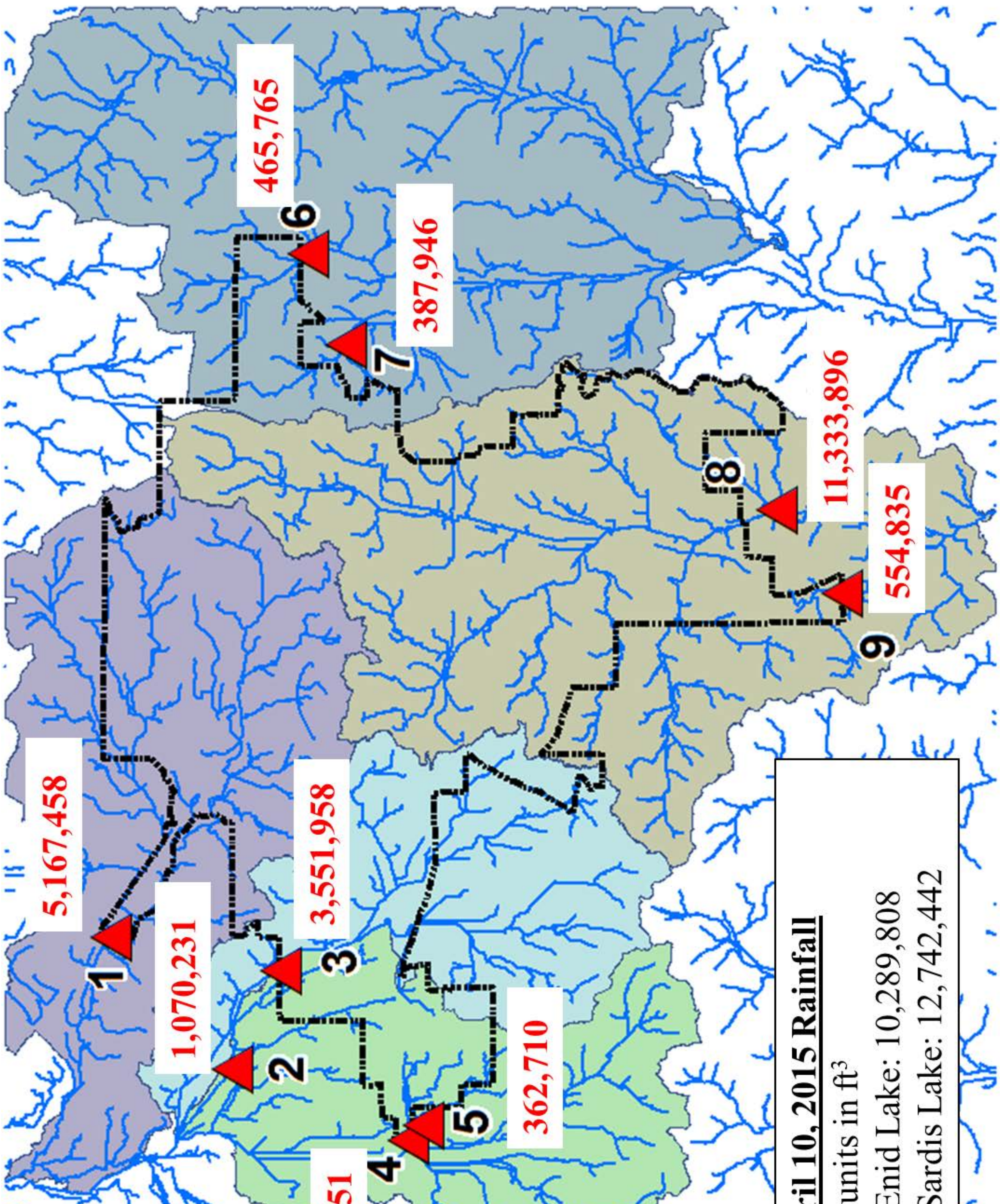

FIGURE 16: Rainfall variability on April 10, 2015 flow accumulation.

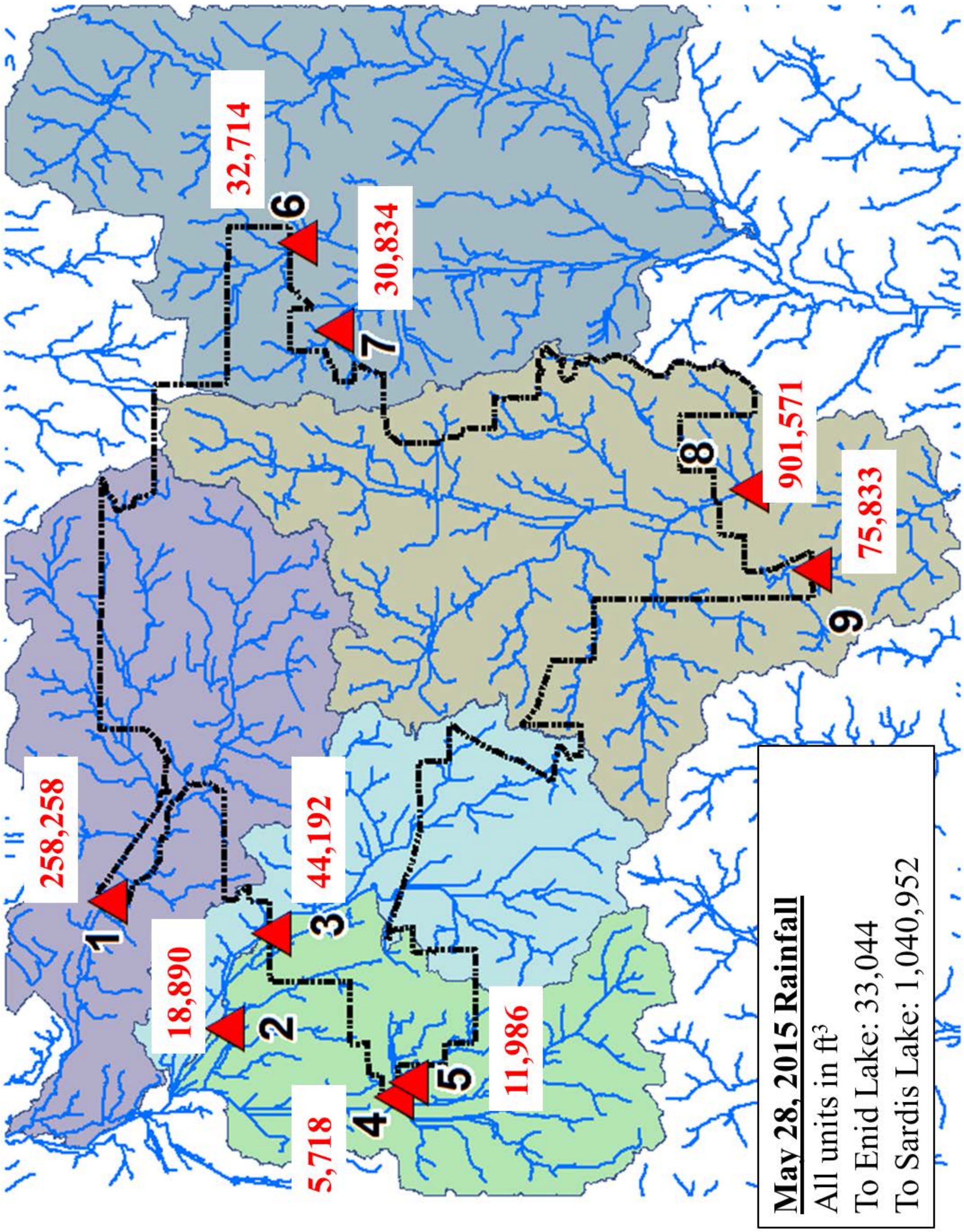

FIGURE 17: Rainfall variability on May 28, 2015 flow accumulation.

To Sardis Lake					
Pour Point	1	2	3	4	5
Watershed Area (ft^2)	155,991,211	25,481,889	135393755	2,097,437	18250719
3/11/2015 ~1.0 in (ft^3)	2,744,792	336,788	1,029,340	44,804	114,792
Runoff (in)	0.21	0.16	0.09	0.26	0.08
4/10/2015 ~2.0in (ft^3)	5,167,458	1,070,231	3,551,958	137,451	362,710
Runoff (in)	0.40	0.50	0.31	0.79	0.24
5/28/2015 ~0.5 in (ft^3)	258,258	18,890	44,192	5,718	11,986
Runoff (in)	0.02	0.01	0.00	0.03	0.01
To Enid Lake					
Pour Point	6	7	8	9	
Watershed Area (ft^2)	24484171	22,260,379	294,443,833	8,509,347	
3/11/2015 ~1.0 in (ft^3)	188,708	168,053	4,253,812	176,090	
Runoff (in)	0.09	0.09	0.17	0.25	
4/10/2015 ~2.0in (ft^3)	465,765	387,946	11,333,896	554,835	
Runoff (in)	0.23	0.21	0.46	0.78	
5/28/2015 ~0.5 in (ft^3)	32,714	30,834	901,571	75,833	
Runoff (in)	0.02	0.02	0.04	0.11	

TABLE 4: Pour point value for a continuous rainfall for March 11, 2015 that had an approximate rainfall of 1.0 inch, April 10, 2015 that had an approximate rainfall of 2 inches, and May 28, 2015 that had an approximate rainfall of 0.5 inches.

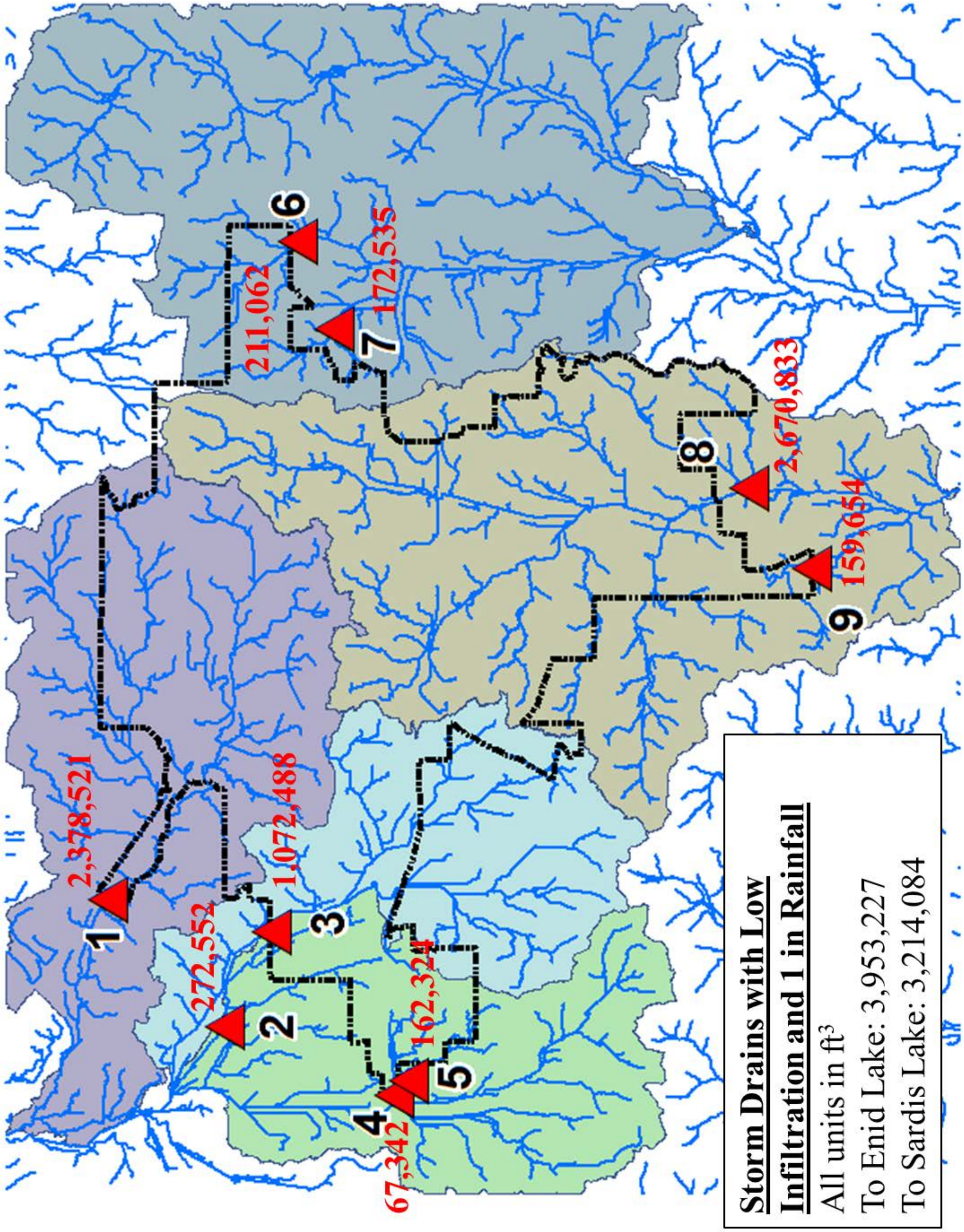

FIGURE 18: Figure 19: Storm drains incorporation in flow accumulation map with a low soil infiltration rate and in a 5 inch rainfall.

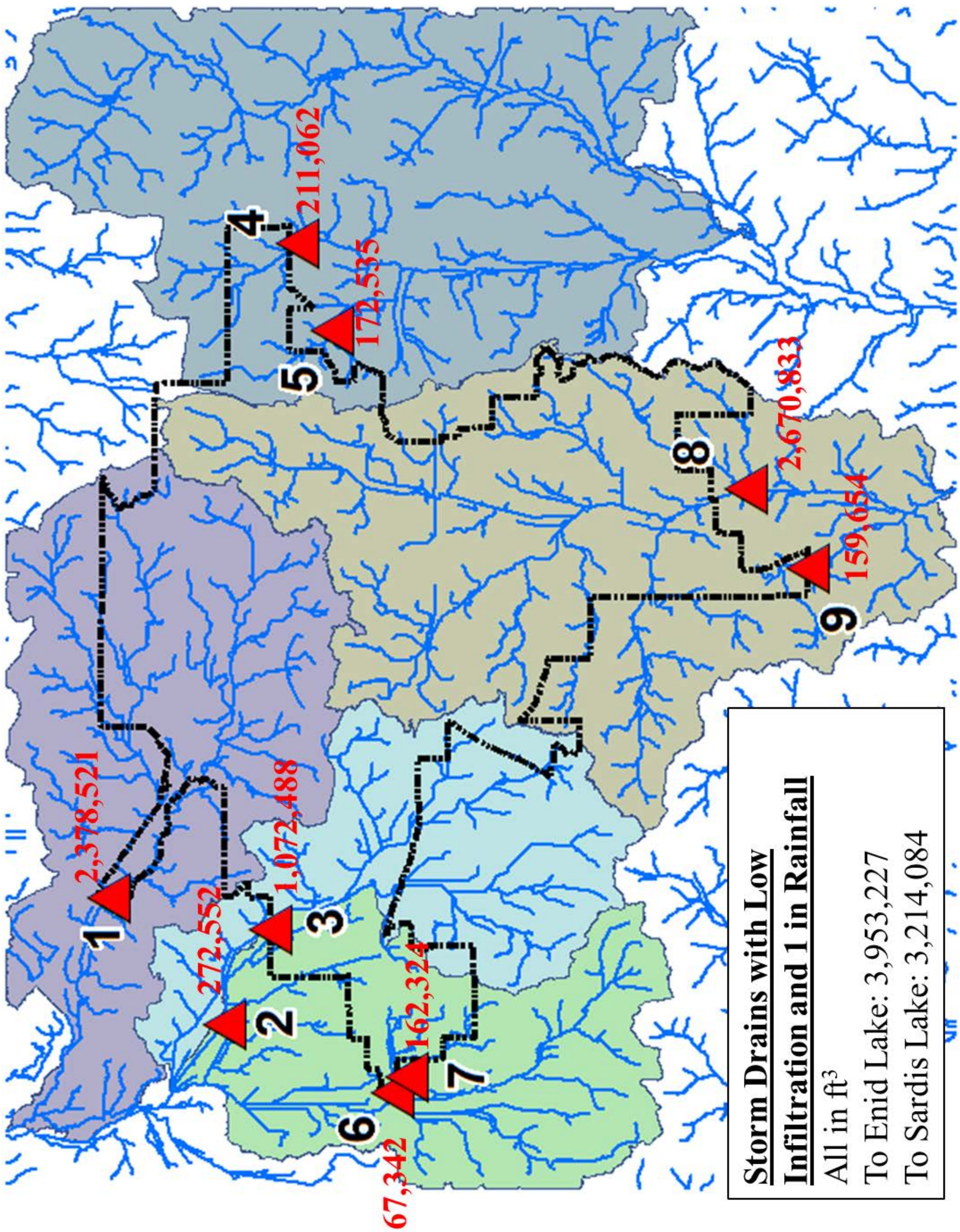

FIGURE 19: Storm drains incorporation in flow accumulation map with a low soil infiltration rate and in a one inch rainfall.

To Sardis Lake					
Pour Point	1	2	3	4	5
Watershed Area (ft^2)	155,991,211	25,481,889	135,393,755	2,097,437	18,250,719
Storm Drain Low 5 in (ft^3)	13,138,396	1,505,762	5,943,374	360,454	890,973
SD Depth (in)	1.01	0.71	0.53	2.06	0.59
Storm Drain Low 1in (ft^3)	2,378,521	272,552	1,072,488	67,342	162,324
SD Runoff (in)	0.18	0.13	0.10	0.39	0.11
To Enid Lake					
Pour Point	6	7	8	9	
Watershed Area (ft^2)	24,484,171	22,260,379	294,443,833	8,509,347	
Storm Drain Low 5 in (ft^3)	1,236,342	973,683	14,796,229	882,194	
SD Runoff (in)	0.61	0.52	0.60	1.24	
Storm Drain Low 1in (ft^3)	211,062	172,535	2,670,833	159,654	
SD Runoff (in)	0.10	0.09	0.11	0.23	

TABLE 5: Flow Accumulation table with incorporated storm drain data for each pour point and at a constant rainfall of 5 inches and 1 inch and a low infiltration rate.

High Infiltration Rate – In the main model the lower rate of infiltration was used because it resulted in more realistic saturation of the soil during a storm event. The higher rate of infiltration was tested to verify that the low rate was indeed the correct and more realistic value to use.

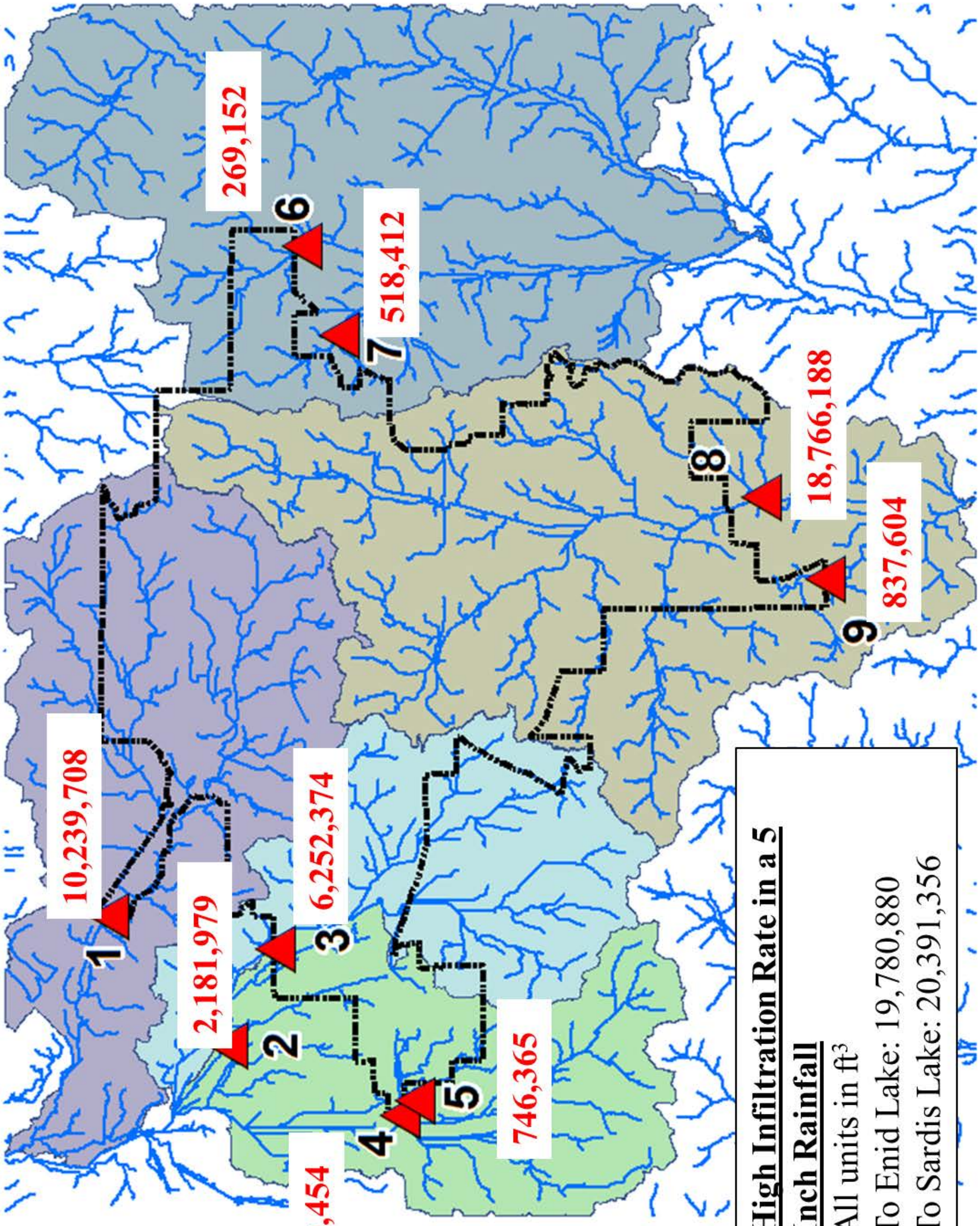

FIGURE 20: High soil infiltration rate in a 5 inch rainfall.

To Sardis Lake					
Pour Points	1	2	3	4	5
High 5in (ft3)	10,239,708	2,181,979	6,252,374	360,454	746,365
Depth HI 5 in (in)	0.79	1.03	0.55	2.06	0.49
To Enid Lake					
Pour Points	6	7	8	9	
High 5in (ft3)	269,152	518,412	18766188	837,604	
Depth HI 5 in (in)	0.13	0.28	0.76	1.18	

TABLE 6: Pour point values of flow accumulation at a high soil infiltration rate in a constant 5 inch rainfall divided by which lake the pour points are in.

In the case of the higher infiltration rate the modeled runoff is unrealistic as everything is absorbed into the soil even during a flood event. Only the 5in was tested by the model as the lower values, 1in, 0.5in, and 0.1in, resulted in no runoff and only show infiltration.

CONCULSIONS

The unweighted flow accumulation map, because it assumes 100% runoff, places an upper limit on the total outflow to the model. By default, the unweighted accumulation assumes a 1 inch rainfall. The highest rainfall amount of 5 inches shows large amount of water flowing out of the city, the most leaving the city through the southern outfalls to Enid Lake. This is supported by the fact that 5 inches in a day, is flood event for the city. The rainfall collection records showed that there is a variation of rainfall through the city. The 13 months of records showed that the southern portion of Oxford received the most rainfall during the storms. The northern portion of the city, near the city airport, received the least amount of rainfall during the time of data collection. A pattern of direction of where the storms would enter the city was also observed through this 13 month period. During the winter, the storms would enter from the northwestern portion of the city and during the summer, the storms would enter 90 degrees to that from the southwest. This variation is based on a short period of record and with climate change the pattern and variation could change through the years.

The use of high resolution of LiDAR data, with a 5 foot by 5 foot cell size was used to find the impervious surfaces and to find the flow direction of the stream in the city. The runoff model was created using impervious cover, incorporating the infiltration rates to the soils, creating constant raster of the ET and maximum/minimum of rainfalls amount recorded over a 13 month period. These parameters were used to create the weight rasters for the flow accumulation calculation. The accumulation maps revealed that during flood events the most water flows out of the city towards to Enid Lake, while during a “spitting” of rain, 0.1 inches of rainfall, only a minimal amount of water flows out of the city. In all cases used in the model, the most runoff goes to Enid Lake because the largest drainage basin in the city limits outflows to that lake. Pour Point 8 (on Burney Branch exiting from the south portion of the city) has the maximum outflow runoff of all the pour points in all models which is expected as it is in the largest drainage basin. The second largest pour point is 1 (on Davidson Creek exiting from the north of the city) with the second largest drainage basin. The most urbanized drainage basin, with the most impervious cover in the city at the moment of this study, is basin 4 on the east side of the city with 42% impervious cover. This model is flexible and can be edited and added to as the city continues to grow in future years.

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LIST OF APPENDICES

APPENDIX A: SOILS IN OXFORD, MS

Soils in Oxford, MS			
Symbol	**Name of Soil**	**Soil Type**	**Infiltration Rate (in/hr)**
2B, 2C	Providence	Silt Loam	0.6-2.0
3C, 3B, 3D3, 3C3	Lexington	Silt Loam	0.6-2.0
4B	Loring	Silt Loam	0.6-2.0
7F	Smithdale	Sandy Loams	
7	Smithdale-Udorthents Complex	Sandy Loams	2.0-6.0
70	Smithdale-Lucy Association	Sandy Loams	
71	Smithdale-Udorthents Association	Sandy Loams	
9	Ochlockonee	Sandy Loams	2.0-6.0
13	Kirkville	Fine Sandy Loams	0.6-2.0
14	Oakimeter	Silt Loam	0.6-2.0
16	Casilla	Silt loam	0.6-2.0
40	Ochlockonee-Bruno Complex	Sandy Loams	2.0-6.0
41	Ochlockonee-Bruno Association	Sandy Loams	2.0-6.0
51	Arkabulta	Silt Loam	0.6-2.0
W, Pt	Water/Pits		0.6-2.0
			(Morris, 1981)

APPENDIX B: RAIN GAUGES LOCATIONS

	Rain Gauges Locations			
#	**Address**	**Easting**	**Northing**	**Owner**
1	1802 West Jackson Apt 10	265278	3805557	Weatherwax
2	1111 Jackson Avenue West	265279	3805549	Old Walmart
3	164 Jeanette Phillips Drive	266444	3804739	Procurement Building
4	413 Cherokee Drive	268892	3806930	Surbeck
5	405 Forest Grove Road	266091	3810775	Easson
6	213 James Circle	264034	3806065	Kolb
7	104 Meadowview Drive	262041	3805963	Holt
8	51 County Road 321	267318	3800053	Kunhart
9	200 Tanner Drive	267850	3799741	Davidson
10	126 Cross Creek Drive	268426	3796317	Aubrey
11	8:504 Rock Spring Drive	277818	3800140	Platt
12	182 Highway 30 E	266418	3804751	Church
13	1619 Highway 30 East	269990	3887819	Swann
14	119 County Road 217			Panhorst
15	1202 Front Street	265729	3804567	Zachos
16	1 Airport Dr.			Airport

APPENDIX C: RAIN COLLECTION DATA

FEBUARY 2015	Date	2/2	2/16	2/21	2/22	2/23	2/26		
OWNER #	**Time**	6:30	16:56	5:53	6:05	5:52	9:02	**TOTAL**	**AVERAGE**
1		1.15	0.6	0.5	2.3	0.3	0.35	5.2	0.87
	Time	N/A	17:10	6:02	6:14	6:08	N/A		
2		N/A	0.7	0.65	2.4	0.5	N/A	4.25	1.06
	Time	N/A	17:17	6:09	6:21	6:19	N/A		
3		N/A	0.5	0.62	2.49	0.5	N/A	4.11	1.03
	Time	7:00	17:34	6:23	6:33	6:35	10:00		
4		1.11	1	0.55	2.55	0.49	0.25	5.95	0.99
	Time	6:45	17:52	6:37	6:45	6:55	9:00		
5		0.87	0.8	0.6	1.38	0.5	0.4	4.55	0.76
	Time	N/A	17:26	10:00	10:00	10:00	10:00		
6		0.4	0.3	0.5	1.75	2.25	0.5	5.7	0.95
	Time	7:20	18:13	6:58	7:01	7:16	9:00		
7		1.1	1.1	0.5	1.9	0.4	0.36	5.36	0.89
	Time	7:40	18:33	7:58	7:19	8:28	8:00		
8		1.1	0.7	0.7	2.1	0.51	0.33	5.44	0.91
	Time	8:00	19:12	7:30	7:25	8:34	9:00		
9		0.7	1	0.6	2	0.5	0.4	5.2	0.87
	Time	8:20	18:55	7:32	7:45	8:50	8:40		
10		0.8	0.6	0.6	2	0.51	0.4875	5.0	0.8
	Time	N/A	19:31	7:46	7:58	9:10	N/A		
11		N/A	0.8	0.75	2.48	0.5	N/A	4.53	1.13
	Time	19:00	18:00	6:30	8:01	9:17	8:00		
12		1.3	0.7	0.6	2.7	0.47	0.35	6.12	1.02
	Time	N/A	17:00	8:00	8:00	8:00	8:00		
13		1.1	0.7	0.5	2.2	0.5	0.4	5.4	0.9
	Time	6:30	18:30	6:30	6:30	6:30	6:30		
14		1.15	0.6	0.55	2.4	0.5	0.5	5.7	0.95
	Time	0:00	20:42	0:00	0:00	0:00	0:00		
15		0.42	0.11	0.16	2.45	0.29	0.65	4.08	0.68

March 2015	Date	2	3	5	9	11	14	15	19	21	22	23	27	30		
Owner #	**Time**	5:54	5:36	11:21	5:45	9:12	6:10	9:09	6:38	5:55	5:55	5:33	5:15	5:04	**TOTAL**	**AVERAGE**
1		0.8	0.2	1.65	0.3	1.2	1.72	0.2	0.35	0.6	0.1	0.4	0.1	0.4	8.02	0.617
	Time	6:01	5:44	NA	5:55	9:02	6:17	9:15	6:46	6:03	6:05	5:45	5:28	5:14		
2		1.15	0.2	NA	0.25	1.15	1.4	0.1	0.35	0.6	0.2	0.5	0.1	0.55	6.55	0.546
	Time	6:13	5:51	15:49	6:04	8:55	6:26	9:22	6:56	6:12	6:13	5:53	5:36	5:23		
3		1.2	0.15	1.97	0.3	1	1.5	0.1	0.32	0.85	0.2	0.51	0.11	0.55	8.76	0.67
	Time	6:25	6:04	16:00	6:16	8:28	6:35	9:30	7:04	6:21	6:23	6:02	5:44	5:33		
4		0.75	0.15	1.62	0.2	1	1.55	0.18	0.3	0.55	0.2	0.5	0.06	0.51	7.57	0.58
	Time	6:38	6:17	16:25	6:31	8:45	6:50	9:43	7:19	6:39	6:36	6:16	5:58	5:46		
5		0.9	0.1	1.25	0.25	0.9	1	0.25	0.55	0.61	0.2	0.4	0.1	0.41	6.92	0.53
	Date	3/2	3/3	3/5	3/9	3/11	3/14	3/15	3/19	3/21	3/22	3/23	3/27	3/30		
	Time	NA	NA	NA	NA	NA	NA	NA	7:34	6:52	6:49	6:29	6:11	6:01		
6		NA	NA	NA	NA	NA	NA	NA	0.1	0.49	0.1	0.42	0.05	0.3	1.46	0.24
	Time	6:40	6:34	16:51	6:55	9:26	7:09	10:10	7:41	6:58	6:55	6:36	6:18	6:08		
7		0.8	0.1	1.61	0.2	0.7	1	0.1	0.3	0.6	0.2	0.4	0.1	0.41	6.52	0.50
	Time	7:11	6:49	11:00	7:13	9:46	7:26	10:29	8:01	7:16	7:15	6:56	6:36	6:27		
8		1.5	0.15	1.97	0.2	0.9	1.28	0.30	0.5	0.7	0.2	0.42	0.1	0.29	8.51	0.656
	Date	2	3	5	9	11	14	15	19	21	22	23	27	30		
	Time	7:17	6:54	17:27	7:21	9:51	7:32	10:35	8:07	7:22	7:24	7:00	6:42	6:33		

Owner #	Date	2	3	5	9	11	14	15	19	21	22	23	27	30	TOTAL	AVERAGE
9		1.6	0.2	1.6	0.29	1	1.2	0.15	0.5	0.87	0.3	0.65	0.1	0.35	8.81	0.678
	Time	7:34	7:11	18:00	7:38	10:36	7:49	10:53	8:24	7:42	7:40	7:15	6:58	6:52		
10		1.35	0.1	1.85	0.2	0.9	1.1	0.27	0.3	0.6	0.17	0.5	0.1	0.32	7.76	0.60
	Time	7:48	7:24	18:09	7:51	10:48	8:02	11:05	8:37	7:53	7:52	7:31	7:11	7:04		
11		1.2	0.2	1.49	0.21	0.9	1.32	0.25	0.3	0.5	0.15	0.59	0.08	0.5	7.69	0.59
	Time	7:52	7:31	NA	7:55	10:52	8:06	11:09	8:41	7:56	7:55	7:35	7:15	7:07		
12		0.7	0.15	NA	0.2	0.9	1.5	0.2	0.3	0.5	0.17	0.5	0.09	0.42	5.63	0.47
	Time	8:00	8:00	8:00	8:00	8:00	8:00	8:00	8:00	8:00	8:00	8:00	8:00	8:00	8:00	
13		0.7	0.1	0.5	0.2	1.2	0.9	0.1	0.4		0.5	0	0	0.5	3.6	0.43
	Time	6:30	6:30	6:30	6:30	6:30	6:30	6:30	6:30	NA	6:30	6:30	6:30	6:30		
14		0.8	0.1	NA	0.2	0.2	1.5	0.1	0.1	NA	1.2	0.5	0.1	0.4	5.2	0.47
	Time	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00		
15		0.67	0.21	0.91	0.2	1.21	0.28	0.35	0.16	0.23	0.08	0.65	0.08	0	5.03	0.39

April 2015	Date	4/10	4/14	4/16	4/18	4/19	4/20	4/25		
Owner #	**Time**	5:05	5:48	5:05	4:53	5:05	5:04	3:42	**TOTAL**	**AVERAGE**
1		2.31	0.72	0.10	0.7	0.4	1.8	2.35	8.38	1.2
	Time	5:15	5:46	5:15	5:01	5:14	5:13	3:51		
2		2.29	0.8	0.19	0.75	0.4	1.8	2.6	8.83	1.26
	Time	5:23	5:40	5:22	5:06	5:20	5:21	3:59		
3		2.3	0.9	0.15	0.8	0.4	2.3	2.7	9.55	1.36
	Time	5:32	5:29	5:31	5:17	5:32	5:30	4:08		
4		2.3	0.95	0.18	0.7	0.35	1.65	2.7	8.83	1.26
	Time	5:46	5:17	5:44	5:30	5:45	5:44	4:21		
5		2.3	0.72	0.10	0.67	0.35	2.15	2.4	8.69	1.24
	Time	6:06	5:58	5:59	5:48	5:58	5:57	4:40		
6		2	0.65	0.10	0.6	0.3	1.9	1.9	7.45	1.06
	Time	6:12	6:03	6:05	5:54	6:04	6:03	4:46		
7		1.98	0.8	0.2	0.79	0.3	1.53	2.45	8.05	1.15
	Time	6:30	6:21	6:25	6:12	6:23	6:21	5:05		
8		2.6	0.65	0.10	0.81	0.4	1.6	2.8	8.96	1.28
	Time	6:36	6:26	6:30	6:17	6:28	6:27	5:12		
9		2.52	0.88	0.10	0.8	0.5	1.1	2.69	8.59	1.23
	Time	6:54	6:45	6:47	6:33	6:46	6:46	5:29	6:54	
10		2.1	0.67	0.18	0.8	0.5	1.2	2.5	7.95	1.14
	Time	7:06	6:56	6:59	6:45	6:58	6:57	5:42		
11		2	0.77	0.10	0.8	0.38	1.3	2.6	7.95	1.14
	Time	7:10	7:00	7:03	6:48	7:02	7:00	5:46		
12		1.95	0.65	0.1	0.7	0.35	1.4	2.6	7.75	1.11
	Time	8:00	8:00	8:00	8:00	8:00	8:00	8:00	TOTAL	AVERAGE
13		2	0.95	0.00	0.7	2.5	2.5	2.5	11.15	1.59
	Time	6:30	6:30	6:30	6:30	6:30	6:30	6:30		
14		1.95	0.75	0.1	0.5	0.4	2	2.5	8.2	1.17
	Time	0:00	0:00	0:00	0:00	0:00	0:00	0:00		
15		1.32	0.92	0.02	1.32	0.09	0.84	2.05	6.56	0.94

May 2015	Date	5/16	5/17	5/18	5/19	5/20	5/26	5/28	5/31		
Owner #	**Time**	5:04	5:05	5:04	5:04	5:02	5:05	5:04	5:05	**TOTAL**	**AVERAGE**
1		0.8	0.25	1.2	0.2	0.3	2.2	0.1	0.3	5.35	0.67
	Time	5:11	5:13	5:13	5:11	5:12	5:13	5:17	5:12		
2		0.75	0.2	1	0.15	0.5	2.05	0.2	0.25	5.1	0.64
	Time	5:20	5:21	5:21	5:19	5:19	5:21	5:23	5:15		
3		0.82	0.19	0.8	0.2	0.505	2.15	0.27	0.5	5.435	0.68
	Time	5:29	5:29	5:30	5:27	5:27	5:29	5:32	5:28		
4		0.5	0.1	0.7	0.2	0.5	1.9	0.23	0.15	4.28	0.54
	Time	5:42	5:43	5:43	5:41	5:41	5:42	5:45	5:42		
5		0.8	0.3	0.7	0.02	0.3	1.8	0.2	0.5	4.62	0.58
	Time	6:00	5:55	5:58	5:54	5:53	5:55	5:57	5:54		
6		0.6	0.25	0.85	0.13	0.5	1.9	0.1	0.12	4.45	0.56
	Time	6:05	6:00	6:04	6:00	5:59	6:01	6:03	6:00		
7		0.3	0.29	0.9	0.16	0.6	1.85	0.16	0.2	4.46	0.56
	Time	6:25	6:18	6:22	6:17	6:16	6:19	6:22	6:18		
8		0.81	0.2	1.2	0.09	0.45	2.5	0.45	0.75	6.45	0.81
	Time	6:30	6:23	6:28	6:22	6:21	6:24	6:27	6:23		
9		1.1	0.5	1.65	0.1	0.3	2.9	0.85	0.9	8.3	1.04
	Time	6:51	6:42	6:46	6:40	6:39	6:43	6:49	6:41		
10		0.9	0.2	1.5	0.09	0.4	2.6	0.5	1.3	7.49	0.94
	Time	7:03	6:53	6:58	6:53	6:53	6:55	7:02	6:53		
11		1.1	0.1	1.15	0.2	0.65	3.1	0.3	0.2	6.8	0.85
	Time	7:07	6:57	7:07	6:57	6:57	6:59	7:06	6:57		
12		0.6	0.1	0.6	0.15	0.6	2.3	0.3	0.35	5	0.63
	Time	8:00	8:00	8:00	8:00	8:00	8:00	8:00	8:00		
13		1	0.6	1.6	0.1	0.5	2.2	0.4	0	6.4	0.8
	Time	6:30	6:30	6:30	6:30	6:30	6:30	6:30	6:30		
14		0.7	0.7	0.8	0.1	0.5	0.2	0.1	0	3.1	0.39
	Time	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00		
15		0.17	0.47	0.41	0	0.02	2.79	0.17	0.22	4.25	0.53

June 2015	Date	6/1	6/9	6/18	6/20	6/21		
Owner #	**Time**	5:05	5:04	5:05	5:04	5:04	**TOTAL**	**AVERAGE**
1		0.3	1.4	1.4	2.8	0.11	6.01	1.2
	Time	6:16	5:11	5:12	5:11	5:11		
2		0.3	2	1.1	3.1	0.5	7	1.4
	Time	5:30	5:23	5:24	5:23	5:23		
3		0.3	1.5	0.7	2.1	0.15	4.75	0.95
	Time	5:38	5:32	5:31	5:32	FORGOT		
4		0.2	2.57	0.2	2.7	FORGOT	5.67	1.42
	Time	5:50	5:45	5:44	5:45	5:44		
5		0.5	2	1.3	2.45	0.55	6.8	1.36
	Time	6:02	5:58	6:02	5:57	5:56		
6		0.02	1.35	0.8	3.09	0.1	5.36	1.07
	Time	6:08	6:04	6:07	6:03	6:02		
7		0.48	1.45	0.25	2.8	0.15	5.13	1.03
	Time	6:29	6:23	6:30	6:22	6:22		
8		0.35	2.5	0.3	2	0.1	5.25	1.05
	Time	6:34	6:29	6:36	6:27	6:28		
9		0.4	3.25	0.1	1.7	0.65	6.1	1.22
	Time	6:53	6:53	6:58	6:46	6:47		
10		0.4	0.55	0.45	1.45	0.62	3.47	0.69
	Time	7:06	7:02	7:11	7:00	7:02		
11		0.4	2.15	0.1	2.5	0.75	5.9	1.18
	Time	7:09	7:05	7:15	7:04	7:05		
12		0.2	2.4	0.05	2.65	0.8	6.1	1.22
	Time	6:53	6:53	N/A	6:55	6:57		
13		0.4	0.9	N/A	2.3	0.52	4.12	1.03
	Time	5:25	5:19	5:19	5:18	5:18		
14		0.7	1.52	0.92	2.8	0.2	6.14	1.228
	Time	0:00	0:00	0:00	0:00	0:00		
15		2.11	0.46	0	0.28	0	2.85	0.57

July 2015	Date	6/30-7/7	7/15	7/16	7/23	7/24	7/25		
Owner #	**Time**	5:06	5:05	5:05	5:07	5:07	5:06	**TOTAL**	**AVERAGE**
1		3.5	0.1	1.18	0.3	0.2	0.3	5.58	0.93
	Time	5:12	5:12	5:12	5:12	5:12	5:11		
2		3.72	0.2	0.8	0.49	0.5	0.5	6.21	1.04
	Time	5:24	5:25	5:23	5:26	5:25	5:23		
3		4.2	0.12	1.1	0.55	0.7	0.3	6.97	1.16
	Time	5:35	5:35	5:35	5:36	5:36	5:33		
4		4	0.3	0.25	0.35	0.6	0.21	5.71	0.95
	Time	5:48	5:48	5:50	5:53	5:43	5:46		
5		4.2	0.15	0.5	0.2	0.8	0.2	6.05	1.01
	Time	6:00	6:01	6:03	6:05	6:03	5:59		
6		3.8	0.2	0.7	0.25	0.3	0.7	5.95	0.99
	Time	6:06	6:07	6:08	6:11	6:09	6:03		
7		4	0.25	0.5	0.3	0.8	0.5	6.35	1.06
	Time	6:32	6:25	6:28	6:34	6:32	6:23		
8		4	0	0.95	0.3	0.3	0.1	5.65	0.94
	Time	6:37	6:31	6:35	6:40	6:25	6:29		
9		4.1	0.37	0.5	0.4	0.35	0.05	5.77	0.96
	Time	6:57	6:51	6:55	7:00	6:55	6:49		
10		4.35	0.1	0.65	0.2	0.3	0.02	5.62	0.94
	Time	7:11	7:07	7:13	7:13	7:08	7:01		
11		4.3	0.1	0.35	0.3	0.7	0.01	5.76	0.96
	Time	7:15	7:11	7:16	7:16	7:12	7:04		
12		4.27	0.2	0.5	0.15	0.8	0.1	6.02	1.00
	Time	7:07	7:03	7:00	6:30	6:30	N/A		
13		4.45	0.1	0.3	0.4	0.5	N/A	5.75	1.15
	Time	5:19	5:20	5:19	5:20	5:20	5:18		
14		4.3	0.22	1.3	0.3	0.4	0.35	6.87	1.15
	Time	0:00	0:00	0:00	0:00	0:00	0:00		
15		6.43	0.37	0	0.22	0.75	0.69	8.46	1.41

August 2015	Date	8/6	8/7	8/8	8/18	8/20	8/24		
Owner #	**Time**	5:05	5:03	5:05	5:02	5:06	5:06	**TOTAL**	**AVERAGE**
1		1.55	0.85	0.5	0.48	0.8	0.2	4.38	0.73
	Time	5:13	5:08	5:12	5:09	5:12	5:13		
2		2.2	1.1	0.8	0.51	0.8	0.6	6.01	1.00
	Time	5:25	5:20	5:24	5:21	5:25	5:21		
3		2.2	0.8	0.8	0.55	0.9	0.35	5.6	0.93
	Time	5:35	5:30	5:34	5:31	5:35	5:31		
4		1.8	1.2	0.98	0	1	0.7	5.68	1.62
	Time	5:49	5:45	5:47	5:45	5:50	5:43		
5		2.8	0.8	1.2	0.4	0.55	1.2	6.95	1.16
	Time	6:10	6:01	6:00	5:58	6:04	5:56		
6		2.7	0.9	0.6	1.15	0.8	0.31	6.46	1.08
	Time	6:16	6:07	6:05	6:04	6:10	6:02		
7		2.62	0.5	0.75	1.5	0.8	0.35	6.52	1.09
	Time	6:36	6:22	6:19	6:20	6:37	6:17		
8		2.41	0.4	0.6	1	1	0.5	5.91	0.99
	Time	6:41	6:27	6:24	6:25	6:42	6:22		
9		2.1	0.8	0.75	0.45	2.08	0.55	6.73	1.12
	Time	7:02	6:44	6:43	6:45	7:00	6:41		
10		1.7	0.5	1.08	0.6	2	0.6	6.48	1.08
	Time	7:14	6:58	6:56	6:58	7:13	6:53		
11		2.6	0.5	1	0	0.81	1.68	6.59	1.10
	Time	7:18	7:01	7:00	7:02	7:21	6:57		
12		2.58	0.5	1.3	0	0.95	1	6.33	1.06
	Time	7:10	6:53	6:52	6:30	6:30	6:30		
13		2.5	0.5	1	0.1	0.9	0.24	5.24	0.87
	Time	5:20	5:15	5:19	5:16	5:20	6:30		
14		1.85	0.7	0.9	1	0.9	0.4	5.75	0.96
	Time	0:00	0:00	0:00	0:00	0:00	0:00		
15		0.35	1.43	0.03	0.87	0.85	1.61	5.14	0.86

September 2015	Date	9/26	9/29		
Owner #	**Time**	5:07	5:05	**TOTAL**	**AVERAGE**
1		0.9	0.2	1.1	0.55
	Time	5:13	5:13		
2		1.7	1.15	2.85	1.43
	Time	5:25	5:24		
3		1.5	1.24	2.74	1.37
	Time	5:31	5:31		
4		REPLACE	0	0	0.00
	Time	5:46	5:46		
5		1.85	1	2.85	1.43
	Time	5:59	5:59		
6		1.2	0.9	2.1	1.05
	Time	6:05	6:05		
7		2.45	1	3.45	1.73
	Time	6:20	6:20		
8		1.85	0.5	2.35	1.18
	Time	6:26	6:26		
9		1.8	1.2	3	1.50
	Time	6:46	6:45		
10		1.6	0.5	2.1	1.05
	Time	7:01	7:00		
11		1.5	0.9	2.4	1.20
	Time	7:06	7:04		
12		1.7	0.1	1.8	0.90
	Time	6:56	10:00		
13		1.5	0.9	2.4	1.20
	Time	6:30	6:30		
14		1.8	0.1	1.9	0.95
	Time	0:00	0:00		
15		0	0	0	0.00

November 2015	Date	11/6	11/7	11/18	11/29	11/30		
Owner #	**Time**	4:49	5:05	5:06	5:04	5:06	**TOTAL**	**AVERAGE**
1		0.35	0.7	2.9	0.4	1	5.35	1.07
	Time	4:42	5:16	5:12	5:10	5:12		
2		0.35	0.8	3	0.5	1.31	5.96	1.19
	Time	4:13	5:22	5:20	5:18	5:19		
3		0.39	0.9	3.25	0.5	1.4	6.44	1.29
	Time	4:20	5:34	5:28	5:25	5:27		
4		0.25	0.8	2.9	0.45	1.3	5.7	1.14
	Time	4:32	5:48	5:41	5:37	5:41		
5		0.3	0.85	2.85	0.5	1.3	5.8	1.16
	Time	4:53	6:01	5:54	5:55	5:55		
6		0.2	0.7	3	0.4	1.09	5.39	1.08
	Time	4:59	6:07	6:00	6:01	6:04		
7		0.3	0.8	3.2	0.45	1.2	5.95	1.19
	Time	5:11	6:21	6:15	6:16	6:18		
8		0.31	1.08	3.1	0.5	1.4	6.39	1.28
	Time	5:17	6:26	6:21	6:22	6:24		
9		0.4	0.95	3.1	0.45	1.4	6.3	1.26
	Time	5:35	6:43	6:39	6:40	6:40		
10		0.4	1.35	3	0.4	1.3	6.45	1.29
	Time	5:47	6:54	6:53	6:53	6:54		
11		0.3	0.71	2.8	0.41	1.3	5.52	1.10
	Time	5:50	6:58	6:56	6:57	6:58		
12		0.25	0.76	2.95	0.5	1.25	5.71	1.14
	Time	7:00	7:00	7:00	6:49	6:50		
13		0.4	0.6	2.8	0.4	1.3	5.5	1.10
	Time	6:30	6:30	6:30	6:30	6:30		
14		0.4	0.4	2.9	0.4	1.2	5.3	1.06
	Time	0:00	0:00	0:00	0:00	0:00		
15		0	0	0	0	0	0	0.00

December 2015	Date	12/1	12/2	12/6	12/13	12/17	12/29		
Owner #	**Time**	4:46	5:07	4:49	5:05	5:06	11:02	**TOTAL**	**AVERAGE**
1		1.3	0.2	0.35	0.89	0.35	4.9	7.99	1.33
	Time	4:51	5:12	4:42	5:12	5:11	6:30		
2		1.42	0.2	0.35	0.9	0.35	7.27	10.49	1.75
	Time	4:59	5:20	4:13	5:19	5:18	11:14		
3		1.46	0.15	0.39	0.9	0.46	4.81	8.17	1.36
	Time	5:06	5:28	4:20	5:27	5:25	11:21		
4		1.38	0.1	0.25	0.99	0.39	4.75	7.86	1.31
	Time	5:19	5:41	4:32	5:40	5:39	11:33		
5		1.45	0.1	0.3	0.65	0.31	4.7	7.51	1.25
	Time	5:32	5:53	4:53	5:57	5:50	11:46		
6		1.3	0.2	0.2	1.02	0.25	4	6.97	1.16
	Time	5:38	5:59	4:59	6:03	6:05	11:52		
7		1.5	0.15	0.3	0.85	0.3	4.8	7.9	1.32
	Time	5:52	6:13	5:11	6:18	6:23	12:07		
8		1.5	0.2	0.31	1.21	0.6	4.7	8.52	1.42
	Time	5:57	6:18	5:17	6:24	6:29	12:12		
9		1.7	0.15	0.4	1.01	0.6	4.8	8.66	1.44
	Time	6:14	6:37	5:35	6:42	6:46	12:29		
10		1.6	0.2	0.4	0.89	0.5	4.7	8.29	1.38
	Time	6:29	6:51	5:47	6:54	6:58	12:47		
11		1.31	0.09	0.3	0.8	0.4	4.7	7.6	1.27
	Time	6:33	6:54	5:50	6:59	7:02	12:45		
12		1.4	0.1	0.25	0.8	0.3	4.72	7.57	1.26
	Time	6:24	6:46	7:00	10:00	10:00	12:37		
13		1.4	0.2	0.4	0.9	0.5	5	8.4	1.40
	Time	6:30	6:30	6:30	6:30	6:30	6:30		
14		1.4	0.2	0.4	0.8	0.4	7.4	10.6	1.77
	Time	0:00	0:00	0:00	0:00	0:00	0:00		
15		0	0	0	0	0	0	0	0.00

January 2016	Date	1/8	1/10	1/21	1/22		
Owner #	**Time**	5:04	5:05	1:20	12:19	**TOTAL**	**AVERAGE**
1		0.1	0.75	0.35	1.71	2.91	0.73
	Time	5:10	5:12	1:24	12:31		
2		0.1	0.72	0.4	2.3	3.52	0.88
	Time	5:17	5:19	1:31	12:49		
3		0.1	0.8	0.4	2.35	3.65	0.91
	Time	5:25	5:27	1:40	1:04		
4		0	0.7	0.35	2.35	3.4	0.85
	Time	5:37	5:40	1:53	1:19		
5		0.11	0.5	0.3	2.1	3.01	0.75
	Time	5:50	5:52	2:07	1:58		
6		0.1	0.6	0.3	2.2	3.2	0.80
	Time	5:56	5:58	2:13	2:04		
7		0.11	0.49	0.3	2.15	3.05	0.76
	Time	6:10	6:12	2:28	2:26		
8		0.1	0.6	0.31	1.8	2.81	0.70
	Time	6:15	6:18	2:34	2:31		
9		0	0.8	0.35	2.01	3.16	0.79
	Time	6:32	6:35	2:52	2:53		
10		0	0.62	0.3	2	2.92	0.73
	Time	6:44	6:48	3:06	3:06		
11		0	0.6	0.3	2.15	3.05	0.76
	Time	6:48	6:51	3:10	3:10		
12		0	0.7	0.3	2.72	3.72	0.93
	Time	10:00	10:00	10:00	10:00		
13		N/A	0.7	0.7	N/A	1.4	0.70
	Time	6:30	6:30	6:30	6:30		
14		0.1	0.7	0.4	N/A	1.2	0.40
	Time	0:00	0:00	0:00	0:00		
15		0	0	0	0	0	0.00

February 2016	Date	2/3	2/16	2/23	2/24	2/25		
Owner #	**Time**	5:04	5:04	5:04	5:05	5:04	**TOTAL**	**AVERAGE**
1		0.49	2.15	0.1	0.85	0.1	3.69	0.74
	Time	5:14	5:12	5:13	5:14	5:13		
2		0.5	2.8	0.15	0.95	0.1	4.5	0.90
	Time	5:23	5:20	5:21	5:25	5:20		
3		0.4	2.65	0.2	1.1	0.11	4.46	0.89
	Time	5:31	5:27	5:28	5:33	5:29		
4		0.4	2.6	0.09	1	0.09	4.18	0.84
	Time	5:43	5:40	5:41	5:45	5:41		
5		0.4	2.81	0.1	0.9	0.09	4.3	0.86
	Time	5:56	5:57	5:53	5:58	5:54		
6		0.5	3.25	0.1	0.85	0.1	4.8	0.96
	Time	6:02	6:04	5:57	6:04	6:00		
7		0.48	2.65	0.09	0.8	0.1	4.12	0.82
	Time	6:16	6:17	6:15	6:18	6:13		
8		0.48	2.78	0.5	0.8	0.1	4.66	0.93
	Time	6:22	6:23	6:20	6:24	6:19		
9		0.45	2.6	0.35	0.98	0.1	4.48	0.90
	Time	6:39	6:40	6:38	6:41	6:39		
10		0.4	2.3	0.11	1	0.09	3.9	0.78
	Time	6:53	6:50	6:50	6:54	6:49		
11		0.5	2.65	0.1	1.2	0.09	4.54	0.91
	Time	6:57	6:55	6:53	6:58	6:53		
12		0.4	2.7	0.09	1.15	0.09	4.43	0.89
	Time	6:48	7:50	7:30	8:00	8:00		
13		0.35	2.8	0.1	1	0	4.25	0.85
	Time	6:30	6:30	6:30	6:30	6:30		
14		NA	2.85	NA	1.2	0	4.05	1.35
	Time	0:00	0:00	0:00	0:00	0:00		
15		0	0	0.72	0.28	0	1	0.20

March 2016	Date	3/2	3/4	3/10	3/11	3/12	3/13	3/14		
Owner #	**Time**	5:08	5:08	5:09	5:08	5:07	5:06	5:07	**TOTAL**	**AVERAGE**
1		0.5	0.5	1	2.5	0.5	1	1.05	7.05	1.01
	Time	5:15	5:13	5:14	5:13	5:12	5:09	5:12		
2		0.4	0.6	1.15	3	0.45	1	0.95	7.55	1.08
	Time	5:22	5:21	5:23	5:20	5:20	5:20	5:19		
3		0.52	0.6	1	3	0.5	1.05	1	7.67	1.19
	Time	5:32	5:28	5:31	5:28	5:28	5:27	5:27		
4		0.49	0.5	1.35	2.68	0.4	0.6	1	7.02	1.00
	Time	5:45	5:42	5:44	5:42	5:40	5:40	5:40		
5		0.2	0.4	1.35	2.5	0.4	1	0.68	6.53	0.93
	Time	5:56	5:58	5:57	5:55	5:56	5:52	5:53		
6		0.3	0.65	1.2	2.6	0.45	0.8	0.91	6.91	0.99
	Time	6:00	6:04	6:03	6:00	6:03	5:56	5:59		
7		0.4	0.5	1.6	2.3	0.4	0.6	0.7	6.5	0.93
	Time	6:16	6:18	6:18	6:14	6:17	6:14	6:13		
8		0.4	0.7	1.35	2.3	0.4	0.88	0.9	6.93	0.99
	Time	6:21	6:23	6:23	6:20	6:23	6:19	6:19		
9		0.25	0.6	0.9	2.35	0.47	0.9	1.16	6.63	0.95
	Time	6:37	6:42	6:43	6:37	6:42	6:39	6:38		
10		0.25	0.5	0.4	2	0.35	0.5	0.9	4.9	0.70
	Time	6:48	6:54	6:56	6:50	6:54	6:50	6:51		
11		0.4	0.5	1.5	1.85	0.3	0.6	0.9	6.05	0.86
	Time	6:52	6:57	7:00	6:53	6:58	6:55	6:54		
12		0.4	0.5	1.9	1.9	0.4	0.5	0.8	6.4	0.91
	Time	8:00	8:00	8:00	8:00	8:00	8:00	8:00		
13		0.5	0.5	1.6	1.7	0.4	0.4	0.7	5.8	0.83
	Time	6:30	6:30	6:30	6:30	6:30	6:30	6:30		
14		0.55	0.5	1.8	2.35	0.4	1	1	7.6	1.09
	Time	0:00	0:00	0:00	0:00	0:00	0:00	0:00		
15		0	0	2.89	0.43	0.71	0.34	0.75	5.12	1.28

VITA

Alexandra Gay Weatherwax was born in San Jose, California May 2, 1991 with her twin Katherine Weatherwax. At the age of three, the family moved to Williamsburg, Virginia. She has one younger brother. She graduated Lafayette High School in June of 2010 with an advanced diploma. She attended the University of Mississippi with the major of geological engineering in May of 2014 and also went to the same University for her Masters in geological engineering. She graduated with her Masters of Science in geological engineering in August of 2017. She aspires to work in the mining industry as she loves to identify minerals in hand sample and thin sections and she loves learning more about the geochemistry of the minerals.